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## THE ENTOMOLOGICAL SOCIETY OF ONTARIO
## OFFICERS AND GOVERNORS
## 2012-2013

**JOURNAL**
*of the*
**ENTOMOLOGICAL SOCIETY OF ONTARIO**

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Prior to the successful Joint Annual Meeting of the Entomological Societies of Ontario and Canada in Guelph your Board met and discussed how to improve the profile of JESO amidst all the competition from the numerous new electronic journals. In his 1999 editorial, past editor Dolf Harmsen had foreseen some of the problems the Proceedings would face with the advent of electronic publishing. Since then, past editor Miriam Richards overcame some of the hurdles and for almost a decade JESO has been publishing electronically. It continues to be printed as hard copy as well. Having both formats has its merits and for historical reasons–it is one of the longest running entomology journals in the world, with no publication breaks since 1871–the hard copy will continue to be published. It is an important part of ESO's heritage. Greater visibility for JESO on the internet is now needed and some good ideas for obtaining this were presented. Ideas for improving JESO's impact were also discussed. One action approved by the Board and promptly implemented by past president Jeff Skevington was to sign an agreement with the Biodiversity Heritage Library to have all back issues scanned, starting with Volume 1 of the Annual Report and make them available on the website, with a two year embargo on the most recent volume.

This year's volume contains five scientific notes and one scientific paper. All but one (on taxonomy) report new species records for Ontario, new distributions or new host records. Two papers are overviews of the past 60 years of JESO papers on two topics. One, on Taxonomy and Faunistics, is mostly a summary. The other, much more detailed and comprehensive is on Biological Control. Both were written to commemorate the 150$^{th}$ meeting of ESO. If there is any trend in the kinds of papers submitted in recent years it is more towards more papers in these areas of entomology and fewer on economically important pest species and their control. Papers on all aspects of entomology are, of course, welcome and my hope is that you, the readers, will continue to find JESO a good place to publish your research.

John T. Huber
Editor

# NEW RANGE RECORDS OF MOSQUITOES (DIPTERA: CULICIDAE) FROM NORTHERN ONTARIO

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**Abstract** *J. ent. Soc. Ont.* 144: 3–14

A survey for mosquitoes at 23 sites in the Ontario Shield and Hudson Bay Lowlands of northern Ontario, Canada, in 2011 and 2012 yielded 19 species, including 16 of *Aedes*, and one each of *Anopheles*, *Coquillettidia*, and *Culesita*. One species, *Aedes pullatus* (Coquillett) is newly recorded for Ontario. Eleven northern range extensions and one southern range extension are reported.

*Published December 2013*

## Introduction

The distributions of many mosquito species (Diptera: Culicidae) in Canada are incomplete. Jenkins and Knight (1952) conducted a survey of larval mosquitoes in southern James Bay. Steward and McWade (1960) published range summaries of species in Ontario. Wood et al. (1979) compiled the most complete account of mosquito distribution in Canada The Canadian Endangered Species Conservation Council (CESCC 2011) assessed the status of many species, including mosquitoes. Yet, areas such as northern Ontario are still relatively little sampled.

Northern Ontario has become the focus of increased mineral exploration and development (FNSAP 2010). Additionally, the area is projected to undergo significant ecological transformation over the next several decades due to climate change (FNASP 2010). Together, these two driving forces create a need for better knowledge of species' distributions in northern Ontario before significant changes occur. A biological diversity survey of different taxa in northern Ontario was initiated in 2009 to address this issue (OMNR 2012). The species composition and diversity information obtained will help determine land use, and management and conservation planning, as well as provide baseline information to determine the impact of mining and climate change.

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Mosquito species lists for particular geographic areas include species that have not been collected there but are assumed to be present based on information from adjacent areas (e.g., Wood et al. 1979; Darsie and Ward 2005). Thus, it is reasonable to expect species to be found in northern Ontario if they have been found in similar habitats and at similar latitudes elsewhere, i.e., in spite of regional climatic differences, we expected to find species that have existing records from both adjacent western Quebec and northern Manitoba because of the large scale continuity of the ecosystems in the boreal and subarctic forests that span these three provinces. For mosquito species whose known distributional limits were either south or north of our study areas, we expected to extend known ranges north or south, respectively. Following this reasoning, and based on the range maps provided by Wood et al. (1979) and Darsie and Ward (2005), we predicted a maximum of 31 species in our surveys. In this paper we report new information on occurrences of known species (range extensions), new collection locations and records of species new to the province for Culicidae in Ontario from surveys of previously unexplored areas of the far north of Ontario. We use both rarefaction and a lognormal analysis to explore the maximum number of species predicted in these areas and to gauge their relative abundances.

## Materials and Methods

Sampling took place within two different northern Ontario ecozones: the Ontario Shield and Hudson Bay Lowlands ecozones (Crins et al. 2009) in 2011 and 2012, hereafter referred to the western and eastern study areas, respectively, as part of a larger biological survey of animal and plant taxa undertaken by the OMNR (2012). The 2011 sampling occurred within 150 km of the First Nations communities near Big Trout Lake and Sandy Lake in the western study area. The 2012 sampling occurred within 150 km of the First Nations community of Fort Albany in the eastern study area. In each year 12 sample sites were randomly selected from the computer generated grid of National Forest Inventory (NFI) points (Gillis et al. 2005). Actual sample locations sometimes differed by as much as 15 km from the NFI coordinates depending on feasibility of landing a helicopter. Our plot locations are the sites at which field camps were established (OMNR 2012). Sample locations were within 1 km of the field camp, which was verified using a handheld GPS (Garmin Rino 530HCx, NAD83, ±3m accuracy). Sampling occurred from 29 May to 17 July in 2011 and 4 June to 5 July in 2012.

Habitats at these sites were dominated by coniferous and shrub wetlands comprised largely of black spruce (*Picea mariana* Britton, Sterns & Poggenb.) and tamarack (*Larix laricina* (Du Roi) K. Koch) as well as shrub and sedge fens, and sphagnum bog. The sites sampled in 2012 in the eastern study area generally had more standing water than those sampled in 2011 in the western study area.

In both years the mosquito component of the sample regimen included daily sampling both by individual collection (*ad hoc*, when mosquitoes were present, approximately 30 minutes total), and a dusk and dawn sweeping with an insect net for 6 minutes at each sampling location. Individual collection consisted of catching mosquitoes that landed on the face, arms, and legs of field crew members using snap cap vials (2.0 ml) before they had a chance to bite. These collections occurred throughout the day and late evening. Individual

specimens in snap vials were preserved dry in the capture vials. Adult mosquitoes collected by sweeping were placed in labeled sample jars with a silica desiccant to prevent deterioration from moisture. A large proportion of them had scales on their thoraces abraded and so could not be identified to species. Therefore, more effort was placed on individual collection in 2012. All specimens were pinned and identified by JLR and DVB using the keys of Wood et al. (1979), and Thielman and Hunter (2007). Nomenclature was based on the WRBU Online Catalog (2013). Voucher specimens were assigned individual specimen numbers (Table 2) and are stored at the Trent University Biology Department in Peterborough, Ontario. Some vouchers are deposited in the Canadian National Collection of Insects, Ottawa.

**Analysis**

Rarefaction analysis for the 2011 and 2012 catch data was performed using software on the University of Alberta website (http://www.biology.ualberta.ca/jbrzusto/rarefact.php). This method relates sampling effort to number of species caught. The total number of species caught each year is used to calculate the expected number of species (with standard deviation) that would have been caught if fewer mosquitoes were sampled overall. Different species numbers for the same total catch sizes indicate community differences such as those due to site, e.g., habitat or phenological, or procedural differences.

We also fit the catch data (Table 1) to a lognormal distribution using the sum of squares method, i.e., Preston's method as described in Ludwig and Reynolds (1988). This allowed us to calculate the expected number of species by estimating the number of rare species not found in the samples. Essentially, it assumes that species of low abundance, e.g., about 1 per 1000 individuals, will only be found if at least 1000 individuals are collected. The lognormal distribution uses the abundance of different species and groups them into octaves or doubled catch classes, e.g., 0–1 individuals, 1–2 individuals, 2–4 individuals, 4–8 individuals and so on, and fits these frequencies to a lognormal curve by aligning the mode. Species that had only one individual caught could go into either the first or second class, so the number was divided between these classes, e.g., if one catches 5 species with only one individual each, then half of these (2.5) are assigned to the 0–1 class, and 2.5 to the 1–2 class (Ludwig and Reynolds, 1988). One of the assumptions of this method is that very rare species will not be sampled, but can be calculated from the area of the normal curve to the left of the 0–1 class or veil line. The biological interpretation is that this class (0–1) would become the 1–2 class if our total catch size was increased. This analysis requires an iterative method to find values for two parameters that provide the best fit: $a$ (width), and $So$ (height). We used the SOLVER optimization add-in function in Microsoft Excel 2007 version for this task.

## Results

We caught 896 mosquitoes in 2011 and 826 in 2012. Mosquitoes caught directly from the face and arms and housed in vials could all be identified to species, whereas only 117 (13%) of individuals from 2011 and 192 (21%) from 2012 sweeping could be identified to species. Species collected and collection locations are summarized in Tables 1 and 2. Twelve species were collected in the western study area in 2011 and 16 species

TABLE 1. Culicidae species collected in 2011 within 150 km of Big Trout Lake and Sandy Lake, and in 2012 within 150 km of Fort Albany.

| Species | Catch per year | | Date(s) captured | | Distribution change for Ontario |
|---|---|---|---|---|---|
| | 2011 | 2012 | 2011 | 2012 | |
| *Aedes abserratus* (Felt and Young) | 1 | 29 | June 17–July 7 | June 8–July 7 | gap infill |
| *Aedes canadensis* (Theobald) | | 2 | | June 25, 28 | new northern record |
| *Aedes cinereus* Meigen | | 1 | | June 23 | new northern record |
| *Aedes communis* (De Geer) | 11 | 2 | June 10, 11 | June 15, 28 | northwestern gap infill |
| *Aedes dorsalis* (Meigen) | | 4 | | June 10 | new northern record |
| *Aedes excrucians* (Walker) | 2 | 2 | July 12 | June 23, 25 | new northern record |
| *Aedes hexodontus* Dyar | 4 | 11 | June 2–July 12 | June 8–13 | gap infill |
| *Aedes impiger* (Walker) | 18 | | June 2 | | northwestern gap infill |
| *Aedes implicatus* Vockeroth | 2 | 3 | June 2–17 | June 8, July 10 | new northern record |
| *Aedes intrudens* Dyar | | 19 | | June 8–26 | new northern record |
| *Aedes nigripes* (Zetterstedt) | 1 | | July 7 | | new southern record |
| *Aedes pionips* Dyar | 28 | 32 | June 2–July 7 | June 8–July 14 | gap infill |
| *Aedes provocans* (Walker) | | 1 | | June 8 | new northern and eastern record |
| *Aedes pullatus* (Coquillett) | | 1 | | June 10 | first record for province |
| *Aedes punctor* (Kirby) | 7 | 35 | June 6–July 3 | June 8–July 7 | gap infill |
| *Aedes rempeli* Vockeroth | | 1 | | June 26 | new northern record |
| *Anopheles earlei* Vargas | 3 | 5 | July 3 | June 8, July 13 | new northern record |
| *Coquillettidia perturbans* (Walker) | 39 | 44 | July 3–15 | June 17 to July 13 | new northern record |
| *Culiseta impatiens* (Walker) | 1 | | June 6 | | new northern record |

in the eastern study area in 2012 (Fig. 1, Table 1). The most abundant species identified in both years was *Coquillettidia perturbans* (Walker). Rare species, i.e., those represented by a single individual collected in either year were *Aedes cinereus* Meigen, *Ae. nigripes* (Zetterstedt), *Ae. provocans* (Walker), *Ae. pullatus* (Coquillett), *Ae. rempeli* Vockeroth and *Culiseta impatiens* (Walker).

Fitting to the lognormal distribution (Fig. 2), the expected number of species was 14.75 from the 2011 catches (fitted parameters $a = 0.24$, $So = 2.0$, Chi sq = 1.23, $p = 0.94$, d.f. = 5) and 23.4 species in the 2012 catches (fitted parameters $a = 0.225$, $So = 2.97$, Chi sq = 5.46, $p = 0.36$, d.f. = 5). By combining the two year's totals, our expected number of species for northern Ontario was 28.2 species (fitted parameters $a = 0.21$, $So = 3.35$, Chi sq = 2.94, $p = 0.82$, d.f. = 6).

Interpretations of new records and range extensions are based on comparison with range maps in Wood et al. (1979).

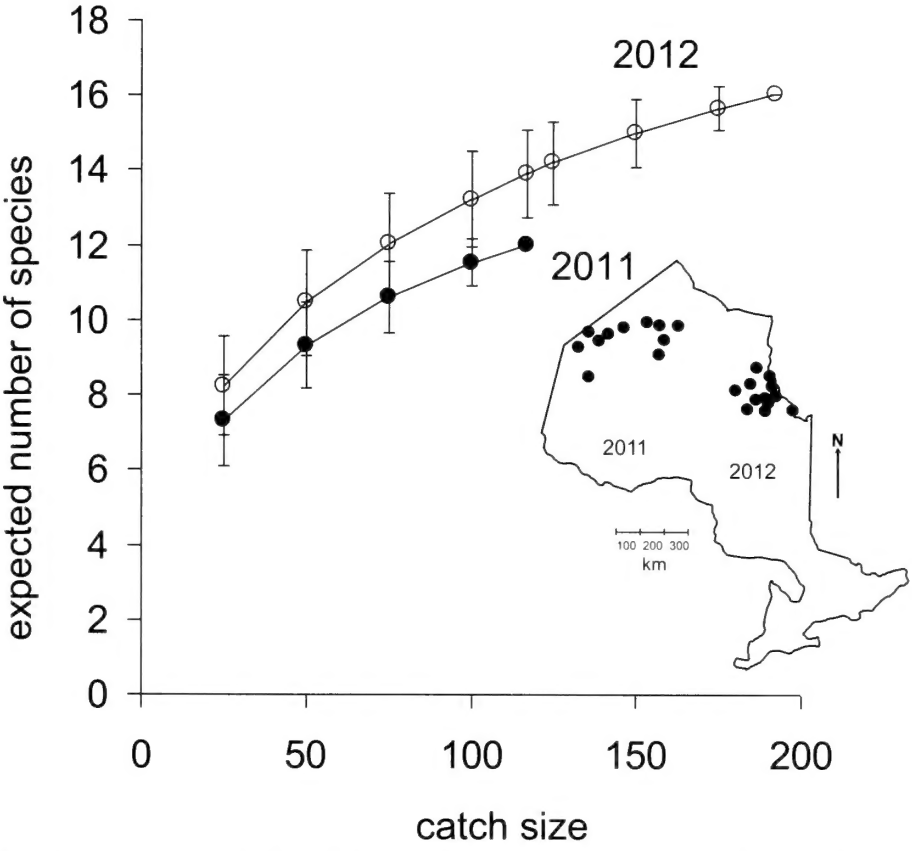


FIGURE 1. Rarefaction analysis of mosquito catches (means and SDs) within 150 km of Big Trout Lake and Sandy Lake in 2011 (closed circles) and within 150 km of Ft. Albany in 2012 (open circles). The inset map of Ontario shows the sampling locations in 2011 and 2012.

TABLE 2. Mosquito species found at each sampling site. Dates indicate when sampling was conducted. Only 11 sample sites listed in 2011 because collections from one of the July 12–21 sites were damaged by a bear. TUIC numbers are voucher specimens in the Trent University Insect Collection.

| TUIC# | Year | 2011 | | | | | | | | | | 2012 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sampling dates | May 31 – June 7 | June 8 – 15 | June 16 – June 23 | June 28 – July 5 | July 6 – July 13 | June 5 – June 11 | June 12 – June 18 | June 19 – June 25 | June 26 – July 2 | July 3 – July 9 | July 10 – July 16 | June 5 – June 11 | June 12 – June 18 | June 19 – June 25 | June 26 – July 2 | July 3 – July 9 | July 10 – June 16 | July 10 – July 16 | | | |
| | Longitude (West) | 89° 6' 28" | 88° 54' 51" | 90° 21' 38" | 93° 2' 33" | 91° 49' 9" | 81° 57' 48" | 80° 23' 11" | 81° 39' 23" | 82° 41' 2" | 83° 17' 24" | 82° 49' 2" | 82° 8' 2" | 83° 2' 25" | 83° 22' 44" | 82° 3' 24" | | | | | | |
| | Latitude (North) | 53° 12' 8" | 53° 45' 35" | 54° 27' 1" | 53° 27' 40" | 52° 27' 37" | 52° 46' 35" | 51° 26' 40" | 51° 58' 8" | 51° 29' 53" | 52° 23' 20" | 52° 28' 27" | 51° 47' 50" | 52° 18' 23" | 51° 21' 22" | | | | | | | |
| | Species | | | | | | | | | | | | | | | | | | | | | |
| 0001 | *Aedes abserratus* | | | | X | | X | X | X | X | X | | | | | | | | | | | |
| 0002 | *Aedes canadensis* | | | | | | X | X | X | X | | | | | | | | | | | | |
| 0003 | *Aedes cinereus* | | | | | | | | X | | | | | | | | | | | | | |
| 0004 | *Aedes communis* | | X | | | | | X | | X | | | | | | | | | | | | |
| 0005 | *Aedes dorsalis* | | | | | | X | | | | | | | | | | | | | | | |
| 0006 | *Aedes excrcians* | | | | | X | | | X | X | | | | | | | | | | | | |

TABLE 2 continued...

| TUIC# | Year | 2011 | | | | | | | | | | | | | 2012 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sampling dates | May 31 – June 7 | May 31 – June 7 | June 8 – 15 | June 8 – 15 | June 16 – June 23 | June 16 – June 23 | June 28 – July 5 | June 28 – July 5 | July 6 – July 13 | July 6 – July 13 | June 5 – June 11 | June 5 – June 11 | June 12 – June 18 | June 12 – June 18 | June 19 – June 25 | June 19 – June 25 | June 26 – July 2 | June 26 – July 2 | July 3 – July 9 | July 3 – July 9 | July 10 – June 16 | July 10 – July 16 |
| 0007 | *Aedes hexodontus* | | | X | | | | | | X | | X | X | | | X | | | | X | | | |
| 0008 | *Aedes impiger* | | X | | | | | | | | X | | | | | | | | | | | | |
| 0009 | *Aedes implicatus* | X | | | | | | | | | | | X | | | | | | | | | | X |
| 0010 | *Aedes intrudens* | | | | | | | | | | | X | | X | | X | X | X | | | | | |
| 0011 | *Aedes nigripes* | | X | | | | | | | | X | | | | | | | | | | | | |
| 0012 | *Aedes pionips* | X | X | X | | X | | X | | | X | X | X | | X | X | X | X | | | | X | |
| 0013 | *Aedes provocans* | | | | | | | | | | | | X | | | | | | | | | | |
| 0014 | *Aedes pullatus* | | | | | | | | | | | X | | | | | | | | | | | |
| 0015 | *Aedes punctor* | | | X | | X | | X | | | | X | X | | | X | X | X | | X | X | | |
| 0016 | *Aedes rempeli* | | | | | | | | | | | | | | | | | X | | | | | |
| 0017 | *Anopheles earlei* | | | | | | | X | | | | | X | | | | | | | X | | | |
| 0018 | *Coquillettidia perturbans* | | | | | | | X | | X | | | | | | | | X | | X | | | X |
| 0019 | *Culiseta impatiens* | X | | | | | | | | | | | | | | | | | | | | | |

**New Ontario record**

*Aedes pullatus* has two distinct distributions, an eastern population in northern Quebec and Labrador and the western population in Alberta, British Columbia, and the Yukon (Wood et al. 1979). The single specimen we collected in the eastern study area is the first record in Ontario and extends the range of the eastern population westward.

**Northward range extensions**

*Aedes canadensis* (Theobald) is a widely distributed species found in forested regions of all Canadian provinces and the Yukon (Steward and McWade 1960). It is known to be found in Moosonee and Moose Factory in Ontario. Our collection was in the eastern study area.

*Aedes cinereus* is a common species in Ontario and has been found in Moosonee, Moose Factory and the town of Kenora (Steward and McWade 1960). Jenkins and Knight (1952) noted that *Ae. cinereus* was the most common larval species that they collected in the southern James Bay area but, oddly, they collected no adults. Our single specimen was collected in the eastern study area.

*Aedes dorsalis* (Meigen) is a rare northern species and in Ontario has only been collected in Moosonee and Moose Factory (Steward and McWade 1960). It was only collected in the eastern study area, which is not surprising because of its relative proximity to these communities.

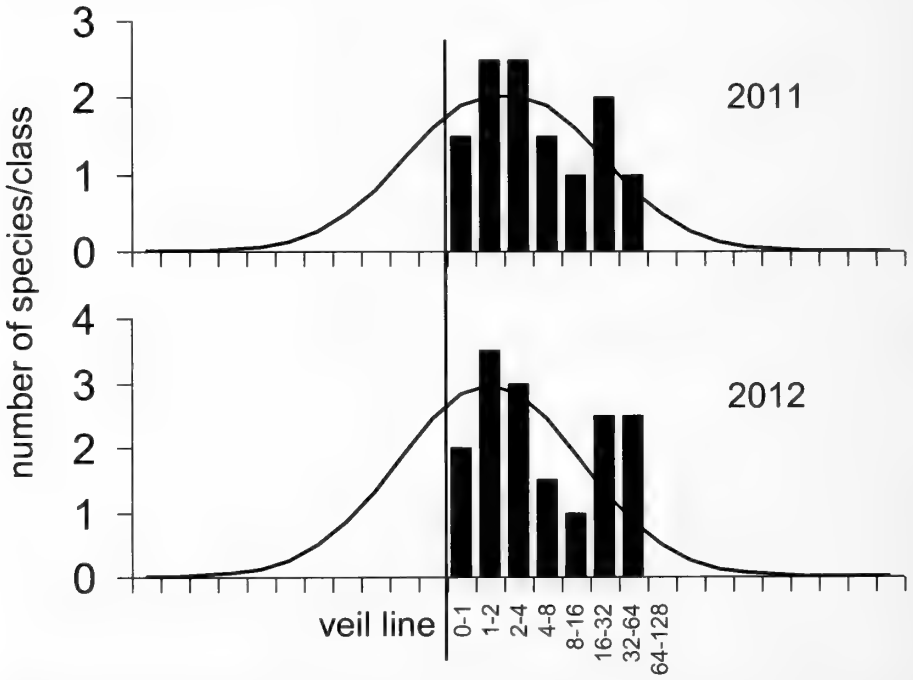


FIGURE 2. Fitted lognormal distributions of mosquito catches within 150 km of Big Trout Lake and Sandy Lake in 2011 and within 150 km of Ft. Albany in 2012. The area of the region left of the veil line represents species that were too rare to be sampled with our methodology.

*Aedes implicatus* (Vockeroth) is common in the northern and central parts of Ontario and has been collected in Moose Factory (Steward and McWade 1960). It was collected in both study areas.

*Aedes excrucians* (Walker) is found throughout North America (Wood et al. 1979). It was collected by Jenkins and Knight (1952) in Moose Factory and Moosonee and by Steward and McWade (1960). Our collection from the western study area provides a record for the gap between the eastern James Bay coast and Manitoba.

*Aedes intrudens* Dyar is found south of the tree line in late spring (Wood et al. 1979). It has been recorded from all provinces (Steward and McWade 1960). The species was common in the eastern study area, but was not found in the western study area.

*Aedes provocans* is a forest species and is a southern species in Ontario (Wood et al. 1979), except for a single record from Great Slave Lake, Northwest Territories. We collected a single specimen in the eastern study area.

*Aedes rempeli* is one of the rarest Canadian species (Vockeroth 1954). However, Wood et al. (1979) suggested that this species may be widely but sparsely distributed in northern Ontario. We caught a single specimen along the Albany River about 150 km upstream from the James Bay coast.

*Anopheles earlei* Vargas is the most common species of this genus in Ontario. Our collections of this species in both study areas extend the known range.

*Coquillettidia perturbans* is common in southern Ontario (Wood et al. 1979). Jenkins et al. (1952) found that this species was very abundant in a spruce forest west of Cochrane, Ontario. In both study areas it was our most abundant species.

*Culiseta impatiens* is a northern species usually found in forested regions and has been recorded from Moose Factory (Steward and McWade 1960). Our single specimen came from the western study area, providing a westward extension of the known range.

**Southward range extensions**

*Aedes nigripes* is an arctic species whose range, according to Wood et al. (1979), did not extend southward into Ontario. However, one recent record exists from Polar Bear Provincial Park (Beresford 2011). One specimens was collected in the western study area in 2011, even farther south than Polar Bear Provincial Park.

**Range gap infills**

*Aedes abserratus* (Felt and Young) is an uncommon species in Ontario (Wood et al, 1979). Steward and McWade (1960) reported the species from Moose Factory. Beresford (2011) collected it in Polar Bear Provincial Park. Our collection of this species in both study areas fills the gap. *Aedes communis* (De Geer) is one of the most widely distributed species in the northern hemisphere. Beckel (1954) stated that this species was rarely collected in the Churchill area of Manitoba because it is non-biting in that area. In Ontario, records show it to be generally present and often abundant throughout the province. This species was well represented (9.4%) in our collections from the western study area, but less so (1%) in the eastern study area.

*Aedes hexodontus* Dyar has been collected in Churchill, Manitoba both as larvae (Vockeroth 1954) and as adults (Beckel 1954), and also from western Quebec and western Ontario (Wood et al, 1979). Our collection fills the gap.

*Aedes impiger* (Walker) is generally found in Nunavut and the Northwest Territories (Steward and McWade 1960). It has been caught in Ontario at Moose Factory and along the Albany River (Steward and McWade 1960) and in Manitoba at Churchill (Downes 1965). Our collections from our western study area fill a gap between Churchill and the James Bay coast in Quebec. Surprisingly, we did not find any in our eastern collections, which are close to James Bay.

*Aedes pionips* Dyar is found in the forests of central and northern Canada, and has been collected from Moose Factory, Ontario (Steward and McWade 1960) and Churchill, Manitoba (Beckel 1954). Not unexpectedly, our collections fill the gap.

*Aedes punctor* (Kirby) is a common species in Ontario and throughout Canada (Steward and McWade 1960). Records are from Moosonee (Jenkins and Knight 1952) and Churchill, Manitoba (Beckel 1954). Our collections are within the expected range but fill distributional gaps in northwestern Ontario.

## Discussion

As expected we produced new distributional records, including both northward and southward range extensions, and filled gaps in known ranges. All of the species we collected are considered by CESCC (2011) to be secure (relatively widespread or abundant), except for five with undetermined status: *Aedes impiger*, *Ae. implicatus*, *Ae. pionips*, *Ae. rempeli* and *An. earlei*.

The rarefaction analysis, which standardizes across different sample sizes, indicates that the eastern region (2012) had slightly more species than the western region (2011). For example, in collections of 100 individuals we would only have been able to catch about 13 species in the east compared to 11 in west (Fig. 1). The lognormal analysis shows the same pattern, with 23.4 species predicted to be in the eastern region compared to 14.75 in the western region (Fig. 2). These analyses reveal that this difference in species richness may be a function of the different regions (e.g., habitats) rather than catch effort. The 2012 eastern study area collections were from sites with lower elevations (1–88 m) than the western sites (148–379 m). However, because these two regions were sampled in different years, we cannot attribute this difference to region alone.

From our survey of the range maps we expected to find up to 31 species. Fitting the lognormal distribution to our overall catch numbers, our expected number of species was 28, a good estimate of species richness of this region.

In fact, we found only 19 species and four of the species we did catch were not expected from the range map analysis: *Aedes nigripes, Ae. provocans, Ae. pullatus, Ae. rempeli.* This means that 16 species from the range map analysis were expected but not found, either due to our sampling methods, phenology, or habitat preferences. Of these, *Wyeomyia smithii* (Coquillett) is fully autogenous and has not been reported bloodfeeding; *Ae. diantaeus* Howard, Dyar and Knab is not found in coniferous forests; *Ae. spencerii* (Theobald) is not found in forest regions; *Ae. sticticus* (Meigen) is generally restricted to

floodwaters of rivers; *Culesita morsitans* (Theobald) and *Culex restuans* Theobald prefer to bloodfeed from birds; *Culex territans* Walker prefers reptiles and amphibians; *Culesita alaskaensis* (Ludlow) and *Ae. mercurator* Dyar are early spring species; *An. walkeri* (Theobald), *Ae. vexans* (Meigen) and *Ae. campestris* Dyar & Knab are primarily nocturnal biters. The remaining four of the expected species are rare, *Ae. riparius* Dyar & Knab, *Ae. flavescens* (Müller), *Ae. fitchii* (Felt & Young) and *Ae. decticus* (Howard, Dyar & Knab) (Wood et al. 1979).

All collection methods have inherent biases associated with them (Muirhead-Thomson 1991). Some important limitations to this survey are that collections occurred at randomly chosen sites (i.e., not selected for high probability of detecting mosquitoes) and using simple methods that were part of a larger diversity survey. The mosquito portion of that survey was limited by the logistics of available time and equipment at these remote sites. A collection effort that focused on targeting mosquitoes alone, within specific habitats, would likely have produced more of the expected species, and the use of $CO_2$ traps of CDC light traps would have produced far larger collections. Nevertheless, this study, despite its limitations, indicates that surveys undertaken in under-sampled regions can produce important baseline information that extends the previously known ranges.

## Acknowledgements

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# TAXONOMY AND FAUNISTICS IN ONTARIO, 1952–2012: PUBLICATIONS IN THE "JOURNAL OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO"

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**Abstract** *J. ent. Soc. Ont.* 144: 15–26

Publications on taxonomy and faunistics that appeared in the Journal of the Entomological Society of Ontario over a 60-year period beginning in 1952 are tabulated. These consist of 60 papers on taxonomy with a total of 700 species, including 125 new ones, described and/or keyed. Almost 100 papers on faunistics (lists, new distributions for North America or parts of North America) were published, with a total of 4700 species mentioned. A brief overview of taxonomy and faunistics as given in JESO volumes is provided.

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## Introduction

Although the Entomological Society of Ontario (ESO) began in 1863, the first report was published in 1871 (covering the year 1870) and publication continued as Annual Reports up to 1958, then from 1959–2001 as the Proceedings of the Entomological Society of Ontario (PESO), and finally from 2002–present as the Journal of the Entomological Society of Ontario (JESO). Because the main goal of the Society at its inception was to publish research on pest insects the first volume was titled "First Annual Report of the Noxious Insects of the Province of Ontario" and subtitled "Prepared for the Agricultural and Arts, and Fruit Growers' Associations of Ontario, on Behalf of the Entomological Society of Canada." The first two articles in it were by the Rev. C. J. S. Bethune, entitled "Insects affecting the apple" and "Insects injurious to grape." The 61 magnificent black-and-white illustrations throughout Vol.1 and the 694 others in the next twelve volumes (illustrations summarized in detail in Vol. 13) stand as a testament to the careful attention to detail in the published papers.

Forward to the 1950s. Glen (1956) compiled a historical overview of entomology in Canada with contributions by different authors in 16 categories, one being Systematic Entomology by G. Holland. One category not treated by Glenn as a separate subdiscipline was faunistics, probably because most taxonomy and biology papers included information on insect distributions, even if it was for a single (usually pest) species, so "faunistics" was too vague to treat as a subdiscipline. To mark the 150th Anniversary of the Entomological Society of Ontario, papers in these two subdisciplines are compiled and briefly discussed

here. Only the past 60 years are treated, beginning with publication date 1953 (vol. 84) to provide a slight overlap with Holland (1956). The subdiscipline of taxonomy, "systematic entomology" of Holland, is complemented with a summary of papers on faunistics. The latter were written by both taxonomists and non-taxonomists, but the non-taxonomists relied heavily on taxonomists for specimen identifications. Over the past six decades both groups of entomologists added a lot of new information on insect distributions in Ontario or Canada. Because they do not include identification keys or taxon descriptions the papers on faunistics are summarized separately from those on taxonomy. Except for 19 papers on particular insect species, and five on insect associations with certain plant species, the faunistics papers exclude studies that detail the biology of single species, most of which are economically important as pests or biological control agents. Such papers are treated by P. Mason (this volume).

**Taxonomy**

Only about 1 taxonomy paper per year (60 in total) was published over the past 60 years (Table 1). These covered almost 700 species of which 125 were described as new. Twenty-five of the papers treated Ontario insects only. Most of them (47) included identification keys, usually to adults but sometimes to larvae or pupa. Somewhat surprisingly, 25 of the papers treated Diptera, 25 treated Hymenoptera but only 7 treated Coleoptera and 1 treated Lepidoptera. About 36 family group taxa and 50 genera were covered. A few papers were more general, treating Lepidoptera, Aculeata, and Symphyta. Two were on nomenclature and type specimens, respectively.

Although most publications in the Annual Reports over its first 80 years treated pest biology and control, the occasional paper foreshadowed the trend over the next 60 years towards more papers on taxonomy and faunistics of insects in general. Fletcher (1902), the founder of the Canadian National Collection of Insects, therefore began an Entomological Record. His aim was not to record facts connected to economic entomology—he called it "practical" entomology—but instead to publish information about other insects, including 1) a record of special rarities taken by collectors, with the various locations and dates, 2) the names of specialists who have devoted particular attention to some order, genus, species, or phases of taxonomic study, 3) the names of any books of note affecting entomology, or connected with any branch of it, which may have been published during the year. For the year, Fletcher summarized collecting thus "The season of 1901 in almost all parts of Canada has been characterized as 'poor' by nearly all collectors heard from." Most of Fletcher's publication gives a literature summary, lists of names and locations of collectors (36 for Lepidoptera, 10 for Coleoptera, and three each for Hymenoptera and Orthoptera), and 8 pages of "notes on captures" compiled by himself and, for Orthoptera, by E. M. Walker. The next year, Fletcher (1903) stated that he hoped at least some of the general collectors in all parts of the country might become specialists on particular taxa because they were urgently needed. He noted that the Lepidoptera and Coleoptera were always fairly well worked but specialists in the other orders were few. Fernald's (1916) paper on life zones in entomology and Felt's (1926) paper on insect distributions presage Walker's (1955) discussion on climate change, mentioned below. So right from the beginning of the 1900s there was interest and concern about taxonomy and distributions, particularly changing ones, of the insect fauna of Canada in general and Ontario in particular.

**Faunistics**

In 1961, C.G. MacNay's yearly article "A summary of the more important insect infestations and occurrences in Canada in 19xx" ceased to be published. Although this series of articles focused almost exclusively on pest insects from across Canada, other noteworthy species were occasionally mentioned. Thus, for 1950 (eighty-first Annual Report) one and a half lines were written on one species not considered a pest: "The noticeable scarcity of reports of this insect [the Painted Lady, *Vanessa cardui* L. (Lepidoptera: Nymphalidae)] contrasts with its widespread abundance in 1949". The rest of the 19-page article summarized the abundance of pest species under several subheadings: general feeders, field crop insects, vegetable insects, fruit insects, insects affecting greenhouse and ornamental plants, insects affecting man and domestic animals, household insects, stored product insects. All the other articles in the volume related to pesticides—it was, after all, shortly after start of the pesticide heyday/revolution. Similar examples occur in the 1951 Annual Report [one mention of a Mourning Cloak butterfly larva, *Nymphalis antiopa* (L.) (Lepidoptera: Nymphalidae)]. Almost invariably the record was in the context of damage to something of economic interest. Preventing damage to crops/animals/humans was seen as perhaps the most important task of entomology. In 1952, 150 years after Fletcher implemented his 'Entomological Record', a section on new records of insects in Canada was added. It included 17 species (5 in Ontario) recorded for the first time either for North America or for Canada or for a particular province. From 1966–1972, H. W. Goble and others published articles under the subheading "Review of infestations and other pests" but restricted their coverage to insects (and nematodes) in Ontario only. Vol. 104 (1973) was the last year such pest summaries were compiled. Thereafter, relatively more attention was paid to insects not of economic importance.

In 1954, a symposium on changing faunal ranges was held, in which various speakers discussed examples (in Lepidoptera, Ephemeroptera, Orthoptera, Hymenoptera, and Araneae) of Carolinian zone insects that showed evidence of a northward shift in distribution. Some crop pests already present in southern Ontario or new entries of insects into the Niagara Peninsula were included. Also exemplified were extensions of faunal ranges in the Prairie Provinces, species spreading with agriculture, species whose ranges fluctuate with climatic cycles, and species with annual northern migrations. Northern shifts in populations of some bird species in the Prairie Provinces and alien pest insect species introduced from abroad were also listed. The eminent E.M. Walker (1955), of odonatological fame, summarized things thus: "But looking back over the sixty odd years since I began to collect insects at De Grassi Point, Lake Simcoe, I have witnessed the gradual decrease in numbers of some species that were once common, until they vanished altogether, and I have seen other species, never known in that territory before, arrive there and in the course of time become firmly established. The species that disappeared were chiefly northern ones, whereas the newcomers were all from the south. This last statement suggests a changing climate that is becoming warmer. The problem, however, is not quite as simple as it seems." I take the Baker symposium, mentioned in Table 2, and Walker's comments as the main post-war starting point for the shift in emphasis on controlling pests to documenting and understanding the Ontario insect fauna in general, with emphasis on changing distributions. However, over 150 years previously Webster (1902) noted general

trends in insect movements around North America. Fernald (1916) and Felt (1926) also wrote about distributions and their significance, showing that within about 30 years since publication of the Annual Reports began entomologists were aware of the importance of tracking insect distributions.

Almost 100 papers on faunistics were published from 1953–2012 (Table 2), with a low of 8 papers in the 1950s to a high of 19 in the 1970s. Many of these are species lists, changes in distributions, or new provincial, country, or continent records. About 4700 arthropod (mostly insect) species in over 20 orders, especially Coleoptera, Diptera and Hymenoptera, are listed. A wide variety of faunistic topics are covered: insects on particular substrates, e.g., decaying mushrooms; in particular habitats, e.g., alvars; visitors to particular species of flowering plants, e.g., *Daucus carota* L. (*Apiaceae*); or natural enemies of particular, non-pest insects, e.g., *Bombus* spp. (Hymenoptera: Apidae). Almost every volume included at least one faunistics paper and a few volumes (104, 141, 142) as many as five. Most papers were restricted to insects of Ontario or parts of Ontario. Occasionally other provinces (Manitoba, Newfoundland, Nova Scotia, Quebec), or the USA or particular US states were treated. Sometimes all of Canada, the Nearctic region (usually America North of Mexico) or the entire New World (an abstract only) was covered.

## Conclusions

Up to the 1950s the Annual Reports stressed pest biology and control, and many detailed papers appeared on their biology often accompanied by excellent line drawings. The Reports also included a smattering of more general papers discussing distributions (read faunistics) and taxonomy. Over the past six decades a greater diversity of papers has appeared, with relatively more emphasis on insects other than pests. On the whole, the Society's journal has provided a fair representation of entomological research in Ontario over most of the past 140 years. This has changed over the past decade. Fewer papers are published in JESO because of the greater number of competing, electronic journals, often with more specialized interests. JESO is therefore perhaps a less reliable tracker of entomological research in the province than previously. Nevertheless, JESO remains a good venue for publishing information on faunistics and taxonomy of Ontario insects.

TABLE 1. Publications on taxonomy in Volumes 82–140 (1952–2012) of the Entomological Society of Ontario.

| Order | Family/other | Genus | Region | Key | # spp. | n. spp. | Author | Other details | Vol. | Year pub. |
|---|---|---|---|---|---|---|---|---|---|---|
| Araneae | Gnaphosidae | *Gnaphosa* | BC, USA (WA) | yes | 2 | | Bennett et al. | | 137 | 2007 |
| Coleoptera | Carabidae | *Coptodera* | New World | yes | 43 | 12 | Shpeley & Ball | | 124 | 1993 |
| Coleoptera | Chrysomelidae | *Altica* | ne. N. Amer. | yes | 2 | | LeSage | on *Vitaceae* | 133 | 2003 |
| Coleoptera | Dytiscidae | | ON | yes | 5 | | James | vernal pools | 100 | 1970 |
| Coleoptera | Monotomidae | *Monotoma* | Canada | yes | 12 | 3 | Bousquet & LaPlante | | 130 | 1999 |
| Coleoptera | Pselaphinae | | BC | yes | 11 | | Chandler | Queen Charlotte Is. | 131 | 2000 |
| Coleoptera | Scarabaeidae | *Pedaridium* | Colombia | no | 1 | 1 | Gill & Vaz-de-Mello | | 133 | 2003 |
| Coleoptera | Scolytinae | *Conophthorus* | | no | 1 | | De Groot | cuticular hydrocarbons | 122 | 1991 |
| Diptera | Anthomyiidae | *Hylemya* | ON | no | 2 | | McLeod | crossing experiments | 95 | 1965 |
| Diptera | Camillidae | *Camilla* | Nearctic | yes | 2 | | Kits et al. | | 143 | 2012 |
| Diptera | Chamaemyiidae | *Pseudodinia* | New World | yes | 17 | 5 | Barber | | 116 | 1985 |
| Diptera | Chironomidae | *Cricotopus* | ON, Salem Creek | yes | 11 | 1 | LeSage & Harrison | | 111 | 1981 |
| Diptera | Clusiidae | *Sobarocephala* | Nearctic | yes | 17 | 2 | Lonsdale & Marshall | | 138 | 2007 |
| Diptera | Culicidae | | ON | yes | 45 | | Steward and Wade | | 91 | 1961 |
| Diptera | Empididae | *Wiedemannia* | USA (AZ) | no | 1 | 1 | Sinclair | | 137 | 2007 |
| Diptera | Ephydridae | *Discomyia* | ON | yes | 3 | | Buck et al. | | 137 | 2007 |
| Diptera | Hybotidae | *Baeodromia* | New World | no | 1 | | Cumming | | 137 | 2007 |
| Diptera | Nycteribiidae | *Basilia* | Nearctic | yes | 6 | | Peterson | | 90 | 1959 |
| Diptera | Opomyzidae | *Geomyza* | Canada | no | 2 | | Wheeler et al. | | 130 | 1999 |
| Diptera | Phoridae | *Cyrtophorina* | Neotropical | yes | 4 | 3 | Brown | | 137 | 2007 |
| Diptera | Simuliidae | *Cnephia, Simulium* | ON | yes | 2 | 2 | Wood | | 93 | 1963 |
| Diptera | Simuliidae | *Prosimulium* | | no | 1 | | Peterson | nomenclature | 95 | 1965 |
| Diptera | Simuliidae | | ON | yes | 44 | | Davies et al. | | 92 | 1962 |
| Diptera | Simuliidae | | ON | yes | 45 | | | | 93 | 1963 |
| Diptera | Sphaeroceridae | *Lotophila* | Holarctic | yes | 5 | 2 | Norrbom & Marshall | | 119 | 1989 |
| Diptera | Sphaeroceridae | *Minilimosina* | New World | yes | 21 | 21 | Marshall | | 116 | 1985 |
| Diptera | Sphaeroceridae | *Rachispoda* | New World | no | 14 | 10 | Wheeler | abstract | 121 | 1990 |
| Diptera | Sphaeroceridae | *Spelobia* | N. Amer. | no | 1 | 1 | Marshall | | 120 | 1989 |
| Diptera | Sphaeroceridae | | ON | yes | 24 | 24 | Marshall & Brown | decaying fungi, Guelph | 115 | 1985 |
| Diptera | Strongylophthalmyiidae | *Strongylophthalmyia* | Canada | yes | 2 | 1 | Barber | | 137 | 2007 |
| Diptera | Tabanidae | *Atylotus* | e. N. Amer. | yes | 10 | 3 | Teskey | | 114 | 1984 |

TABLE 1 continued....

| Order | Family/other | Genus | Region | Key | # spp. | n. spp. | Author | Other details | Vol. | Year pub. |
|---|---|---|---|---|---|---|---|---|---|---|
| Diptera | Tabanidae | *Merycomyia* | Nearctic | no | 2 | | Pechuman | | 94 | 1964 |
| Diptera | Tabanidae | | ON | yes | 87 | | Pechuman et al. | list of MB species | 91 | 1961 |
| Hymenoptera | Aculeata | *Cerceris, Chelostoma* | e. Canada | yes | 23 | | Buck et al. | new records | 136 | 2006 |
| Hymenoptera | Apidae | *Ceratina* | ON | yes | 3 | | Rehan & Richards | problematic spp. | 139 | 2008 |
| Hymenoptera | Apidae | | ON | yes | 17 | | Romankova | Epeolini | 135 | 2006 |
| Hymenoptera | Braconidae | *Euphoriella* | Nearctic | yes | 10 | 7 | Loan & New | | 102 | 1972 |
| Hymenoptera | Braconidae | *Leiophron* | ON | yes | 2 | 2 | Loan | on *Lygus* | 100 | 1970 |
| Hymenoptera | Braconidae | *Trachagathis* | South America | yes | 3 | 2 | Sharkey | | 137 | 2007 |
| Hymenoptera | Chalcidoidea, Cynipoidea | | | no | | | Sarazin | primary types in CNC | 118 | 1988 |
| Hymenoptera | Chrysididae | *Elampus* | Nearctic | yes | 7 | 2 | Huber & Pengelly | | 108 | 1980 |
| Hymenoptera | Chrysididae | *Elampus* | Cuba, Puerto Rico | yes | 2 | 2 | Huber & Pengelly | | 108 | 1980 |
| Hymenoptera | Colletidae | *Colletes* | ON | yes | 16 | | Romankova | | 134 | 2004 |
| Hymenoptera | Colletidae | *Hylaeus* | ON | yes | 8 | | Romankova | | 138 | 2007 |
| Hymenoptera | Colletidae | *Hylaeus* | Canada | yes | 2 | | Sheffield et al. | non-native bee list | 142 | 2011 |
| Hymenoptera | Crabronidae | *Hoplisoides* | Canada | yes | 8 | | Buck | | 137 | 2007 |
| Hymenoptera | Diprionidae | *Neodiprion* | ON | no | 6 | | West et al. | serology | 89 | 1958 |
| Hymenoptera | Eucharitidae | | Nearctic | yes | 16 | 5 | Heraty | | 116 | 1985 |
| Hymenoptera | Megachilidae | | ON | yes | 5 | | Romankova | Anthidiini | 134 | 2004 |
| Hymenoptera | Mymaridae | *Anaphes* | Nearctic | yes | 9 | | Huber | *fuscipennis* group | 123 | 1992 |
| Hymenoptera | Mymaridae | *Anaphes* | Nearctic | yes | 13 | | Huber | *crassicornis* group | 135 | 2006 |
| Hymenoptera | Mymaridae | *Camptoptera* | World | yes | | 2 | Huber & Lin | key to genera | 130 | 1999 |
| Hymenoptera | Mymaridae | *Eustochus* | World | yes | 8 | 4 | Huber & Baquero | | 138 | 2007 |
| Hymenoptera | Mymaridae | *Ooctonus* | Nearctic | yes | 14 | 5 | Huber | | 143 | 2012 |
| Hymenoptera | Mymaridae | *Stephanodes* | World | yes | 5 | 1 | Huber & Fidalgo | | 128 | 1997 |
| Hymenoptera | Perilampidae | *Jambiya* | Israel, Yemen | no | 1 | 1 | Heraty & Darling | | 138 | 2007 |
| Hymenoptera | Symphyta | | ON | yes | 23 | | Lindquist & Miller | on birch, alder | 100 | 1970 |
| Hymenoptera | Symphyta | | ON | yes | 14 | | Lindquist & Miller | on spruce, balsam fir | 102 | 1972 |
| Isopoda | | | ON | yes | 18 | | Belaoussof et al. | | 129 | 1998 |
| Lepidoptera | | | ON | yes | 19 | | Lindquist & Miller | on alder | 100 | 1970 |

TABLE 2. Publications on faunistics in Volumes 82–140 (1952–2012) of the Entomological Society of Ontario.

| Vol. | Publ. year | Author(s) | Area | Locality | Key words | Order | Family | Genus | # spp. | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 1952 | Robinson | MB | | predators of | | Tetranychidae | | 23 | |
| 83 | 1952 | Judd | ON | London | reared from galls | Diptera | Cecidomyiidae | *Rabdophaga* | 16 | *strobiloides* Walsh |
| 84 | 1952 | Fox & Stirrett | Can. | | tobacco pests, catalogue | | | | ca. 70 | |
| 84 | 1953 | Pengelly | ON | southern | alfalfa pollination | Hymenoptera | Apoidea | | ca. 25 | |
| 86 | 1955 | Baker (symposium) | ON | | changing faunal ranges | | | | | |
| 87 | 1957 | Miller | ON | | pest range changes | | | | 6 | |
| 87 | 1957 | Pechuman | Can. | | new for country | Diptera | Tabanidae | | 12 | |
| 87 | 1957 | Pengelly | ON | Bruce Co. | records | Araneae | | *Latrodectus* | | *mactans* (Fabricius) |
| 88 | 1958 | Hicks | ON | | new for province | Coleoptera | Curculionidae | *Brachyrhinus* | | *raucus* (Fabricius) |
| 91 | 1961 | Atwood | ON | | list, review | Hymenoptera | Diprionidae | | 16 | |
| 91 | 1961 | Teskey | ON | | list | Diptera | Hypodermatinae | | 2 | |
| 92 | 1962 | Knerrer & Atwood | ON | | list | Hymenoptera | Halictidae (non-parasitic) | | 59 | |
| 93 | 1963 | Benedict | ON | Windsor area | list | Diptera | Culicidae | | 17 | |
| 93 | 1963 | Peterson | USA, Mex. | | records | Diptera | Nycteribiidae | | 5 | |
| 94 | 1964 | Knerrer & Atwood | ON | | list | Hymenoptera | Andrenidae | | 70 | |
| 95 | 1965 | Graves | ON | | distribution | Coleoptera | Cicindellidae | | 13 | |
| 96 | 1966 | Belton & Galloway | ON | Belleville area | phenology | Diptera | Culicidae | | 24 | |
| 97 | 1967 | Vickery & Kevan | ON | | list | Orthopteroidea s.l. | | | 127 | |
| 97 | 1967 | Judd | ON | London | pond-emerging insects | | | | ca. 60 | |
| 97 | 1967 | Knerrer & Atwood | ON | Toronto area | inquilines, parasitoids | Hymenoptera | social Halictidae | | 6 | |
| 98 | 1968 | Riotte | ON | Halton Co. | new for province | Lepidoptera | Pieridae | *Pieris* | | *virginensis* Edwards |
| 98 | 1968 | McClanahan et al. | ON | Essex Co. | new for province | Coleoptera | Chrysomelidae | *Oulema* | | *melanopus* (L.) |

TABLE 2 continued...

| Vol. | Publ. year | Author(s) | Area | Locality | Key words | Order | Family | Genus | # spp. | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| 98 | 1968 | Judd | ON | Byron Bog | list | Odonata | | | 22 | |
| 98 | 1968 | Judd | ON | Byron Bog | list | Coleoptera | Dytiscidae, Hydrophilidae | | 26 | |
| 99 | 1969 | Judd | ON | Byron Bog | insects visiting | | *Asteraceae* | *Eupatorium* | 43 | *perfoliatum* L. |
| 99 | 1969 | Munroe | ON | | distribution, postglacial origin | | | | | |
| 100 | 1970 | Judd | ON | southern | insects visiting | | *Apiaceae* | *Daucus* | 66 | *carota* L. |
| 100 | 1970 | James et al. | ON | southeastern | list | Diptera | Culicidae, Chaoboridae | | 40 | |
| 101 | 1971 | Judd | ON | Byron Bog | insects visiting | | *Asteraceae* | *Taraxacum* | 24 | *officinale* Weber |
| 101 | 1971 | Dondale | ON | Belleville area | list, mown field | Araneae | | | 150 | |
| 101 | 1971 | Brower & Brower | ME | | reared from pitcher plants | Lepidoptera | | | 3 | |
| 102 | 1972 | New & Loan | ON | Belleville area | list | Psocoptera | | | 24 | |
| 102 | 1972 | Judd | ON | Owen Sound | pollinating | | Vespidae | *Epipactis* | 4 | *helleborine* (L.) |
| 102 | 1972 | Dutchback et al. | ON | Thunder Bay | new record for province | Coleoptera | Carabidae | *Trechus* | | *crassiscapus* Lindroth |
| 103 | 1973 | Hagley & Hikichi | ON | | unsprayed apple orchards, major pests | Lepidoptera, Diptera Coleoptera | | | 20 | |
| 104 | 1974 | Foott | ON | Essex Co. | corn fields | Coleoptera | Coccinellidae | | 6 | |
| 104 | 1974 | MacFarlane | N.Am. | | arthropod predators of | Hymenoptera | Apidae | *Bombus* | ca. 30 | |
| 104 | 1974 | Watson | ON | Sudbury | new for province | Diptera | Cecidomyiidae | *Dasineura* | | *aceris* (Shimer) |
| 104 | 1974 | Freitag & Ryder | ON | Granite I., Black Bay | arthropods in gull nests | | | | ca. 30 | |
| 104 | 1974 | Larochelle | QC | Anticosti I. | | Coleoptera | Carabidae | | 83 | |
| 105 | 1975 | Hagley & Hikichi | ON | | predators in unsprayed apple orchards | Insecta, Acari | | | ca. 110 | |

TABLE 2 continued...

| Vol. | Publ. year | Author(s) | Area | Locality | Key words | Order | Family | Genus | # spp. | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| 105 | 1975 | Vickery & Kerr | ON | | list, additions | Grylloptera | | | 26 | |
| 106 | 1976 | Morris | NL | | butterfly list | Lepidoptera | | | 61 | |
| 107 | 1977 | Judd | ON | Haldimand Co. | list | Isopoda | | | 7 | |
| 108 | 1978 | Judd | ON | Haldimand Co. | list | Opiliones | | | 7 | |
| 109 | 1979 | Tomlin & Nagy | ON | southwestern | new for province | Diplura | Japygidae | | 1 | |
| 110 | 1980 | Broadbent & Tomlin | ON | Guelph, London | list, corn field, pasture | Acari | | | 76 | |
| 110 | 1980 | Tyler & Ellis | ON | Elora | corn fields | Coleoptera | Carabidae | | 23 | |
| 112 | 1982 | Tomlin | ON | southern | new for province | Protura | | | > 2 | |
| 114 | 1984 | Judd | ON | Haldimand Co. | insects visiting | | *Dipsacaceae* | *Dipsacus* | 41 | *fullonum* L. |
| 115 | 1985 | Brown & Marshall | ON | Guelph, London | list, in decaying fungi | Diptera | Phoridae | | 36 | |
| 117 | 1987 | Sinclair & Marshall | ON | southern | madicolous habitats | | | | 76 | |
| 117 | 1987 | Pendreigh & Marshall | ON | Algonquin Prov. Pk. | sphagnum bog | Diptera | Sphaeroceridae | | ca. 23 | |
| 118 | 1988 | Williams & Williams | Can. | | freshwater springs | Trichoptera | | | ca. 64 | |
| 118 | 1988 | Peck & Kaulbars | USA | | distribution, bionomics | Coleoptera | Silphidae | | 27 | |
| 118 | 1988 | Vickery & Scudder | Can. | | list | Orthopteroidea s.l. | | | 300 | |
| 119 | 1989 | Rothman & Lorne | ON | Toronto | landfill | Acari | Phytoseeidae | | 11 | |
| 120 | 1989 | Nystrom & Evans | ON | Newmarket | new for North America | Hymenoptera | Tenthredinidae | *Scolioneura* | | *betuleti* (Klug) |
| 121 | 1990 | Swann | ON | St. Joseph I. | | Diptera | Sphaeroceridae | | 2 | |
| 121 | 1990 | Wheeler | New World | | | Diptera | Sphaeroceridae | | 10 | |
| 122 | 1991 | Smith | Can. | Guelph | new for Canada | Hymenoptera | Megachilidae | *Megachile* | | *manicatum* (L.) |
| 122 | 1991 | Marshall | Can. | | collections to track faunal change | | | | | |

TABLE 2 continued...

| Vol. | Publ. year | Author(s) | Area | Locality | Key words | Order | Family | Genus | # spp. | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| 125 | 1994 | Harper & Ricker | ON | | distribution | Plecoptera | | | 78 | |
| 126 | 1995 | Skidmore | Can., AK | | list | Collembola | | | 412 | |
| 126 | 1995 | Myles | ON | | new records | Isoptera | | | 3 | |
| 127 | 1996 | Bright | ON | Niagara area | parasitoids/predators | Coleoptera | Scolytinae | *Tomicus* | 11 | *piniperda* (L.) |
| 127 | 1996 | Catling | ON | southern, eastern | northward expansion | Odonata | Coenagrionidae | *Enallagma* | | *civile* (Hagen) |
| 128 | 1997 | Skevington & Carmichael | ON | Lampton Co. | list | Odonata | | | 66 | |
| 129 | 1998 | Suger et al. | ON | southern | oak savannah | Hymenoptera | Symphyta, Aculeata | | 145 | |
| 129 | 1998 | McCafferty & Randolph | Can. | | list | Ephemeroptera | | | 321 | |
| 131 | 2000 | Paquin & Lesage | QC | Gaspésie Park | list | Araneae | | | 105 | |
| 132 | 2001 | McCorquodale | ON | | new records | Coleoptera | Cerambycidae | | 14 | |
| 132 | 2001 | Bouchard et al. | ON | | Auchenorhyncha in alvars | Hemiptera | | | 18 | |
| 132 | 2001 | Paquin & Dupérré | QC | western | boreal forest | Coleoptera | | | 757 | |
| 134 | 2004 | Buck | ON | | list | Hymenoptera | Sphecidae, s.l. | | 278 | |
| 134 | 2004 | Paiero et al. | Can. | | new for country | Hemiptera | | | 39 | |
| 134 | 2004 | Godsoe | ON | | extirpation in | Hymenoptera | Pompilidae | *Ceropales* | | *bipunctata* Say |
| 134 | 2004 | Paiero & Buck | Can. | | new for Canada | Hymenoptera | Apoidea | | 4 | |
| 135 | 2006 | Marshall et al. | Can. | | new records/distributions | Orthoptera | | | 16 | |
| 136 | 2006 | Bouchard et al. | ON | | alvars | Coleoptera | Carabidae | | 142 | |
| 137 | 2007 | Galloway | MB | | parasites of Caprimulgidae | Acari, Phthiraptera | | | 2 | |

TABLE 2 continued...

| Vol. | Publ. year | Author(s) | Area | Locality | Key words | Order | Family | Genus | # spp. | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| 137 | 2007 | Turnock et al. | MB | | canola fields | Hymenoptera | Apidae | *Bombus* | 15 | |
| 138 | 2007 | McCorquodale et al. | ON | | species decline, loss | Coleoptera | Cerambycidae | | 11 | |
| 139 | 2008 | Paquin | QC | | additions | Araneae | | | 8 | |
| 140 | 2009 | Cutler & Rogers | NS | | new for province | Coleoptera | Scarabaeidae | *Maladera* | | *castanea* (Arrow) |
| 140 | 2009 | Skevington & Goolsby | AZ | | new host records | Diptera | Pipunculidae | | 2 | |
| 141 | 2010 | Vickruck et al. | ON | southern | natural enemies | Hymenoptera | Apidae | *Ceratina* | 8 | |
| 141 | 2010 | Catling et al. | ON | | alvars | Orthoptera | | | 89 | |
| | | | | | | Coleoptera, Araneae | | | | |
| 141 | 2010 | Colla & Dumesh | ON | | phenology | Hymenoptera | Apidae | *Bombus* | 18 | |
| 141 | 2010 | Procter et al. | ON | south, central | hardwood forests | Coleoptera | Curculionidae | | 26 | |
| 141 | 2010 | Sheffield et al. | ON | St. Catharines | new for province | Hymenoptera | Apidae | *Megachile* | | *ericetorum* Lepeletier |
| 142 | 2011 | Douglas | N. Am. | | new records | Coleoptera | Elateridae | | 16 | |
| 142 | 2011 | Beresford | ON | Polar Bear Prov. Pk. | insects, list | | | | 44 | |
| 142 | 2011 | Fogain & Graff | Can. | | new for country | Hemiptera | Pentatomidae | *Hyalomorpha* | | *halys* (Stål) |
| 142 | 2011 | McAlpine & Olden | ON | Renfrew Co. | new for province | Isopoda | Trichoniscidae | *Hyloniscus* | | *riparius* (Koch) |
| 142 | 2011 | Sheffield & Williams | AK | Attu I. | new for North America | Hymenoptera | Apidae | *Bombus* | | *distinguendus* Morawitz |
| 143 | 2012 | Denomme-Brown & Otis | ON | southern | distribution | Lepidoptera | Lycaenidae | *Callophrys* | | *gryneus* (Hübner) |
| 143 | 2012 | Huber & Read | ON | Niagara on the Lake | new for province | Hymenoptera | Cynipidae | *Dryocosmus* | | *kuriphilus* Yasumatsu |

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# BIOLOGICAL CONTROL IN ONTARIO 1952–2012: A SUMMARY OF PUBLICATIONS IN THE "JOURNAL OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO"

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## Introduction

Biological control involves the manipulation of natural enemies to regulate populations of pest species. This biologically based approach is key to the successful management of pest species, and requires a sound understanding of the pest, its associated organisms and their interactions. A first step is to understand the biology of a target species which allows determination of such things as number of generations per growing season, life stages that cause damage, and life stages that are appropriate for control. Knowledge of the natural enemy community associated with a pest species will provide an indication of the potential for biological control to suppress and maintain populations below economically damaging levels. In Ontario, biological control began in 1882 when W. Saunders imported *Trichogramma minutum* Riley (Hymenoptera: Trichogrammatidae) from New York state for release in Ontario gardens to control the Imported Currantworm *Nematus ribesii* (Scopoli) (Hymenoptera: Tenthredinidae) (Glen 1962).

The present compilation summarizes the biological control contributions published in the *Annual Report of the Entomological Society of Ontario* / *Proceedings of the Entomological Society of Ontario* / *Journal of the Entomological Society of Ontario* (together, JESO) from 1952–2012 as part of the commemorative activities to celebrate the 150th anniversary of the Entomological Societies of Canada and Ontario. Although most cover work in Ontario, several (e.g., James 1952; Maxwell and Morgan 1952; Robinson 1952), address studies in other regions. Glen (1956) summarized work in entomology, including biological control in Canada to 1956 and this should be consulted for information on studies prior to 1952. It should be noted that studies published in JESO document only a portion of the work on each species. More comprehensive accounts can be found in the *Biological Control Programmes in Canada* series (McLeod et al. 1962; Kelleher et al. 1971; Kelleher and Hulme 1984; Mason and Huber 2002; Mason and Gillespie 2013).

Several contributions provide general summaries of the knowledge at the time of their publication. Chant (1957) provided an overview of papers relevant to biological control

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presented at the 10th International Congress of Entomology. Cameron (1952) conducted a review of diseases of insects to 1951 and Cameron (1969) reviewed the problems and prospects in the use of pathogens for insect control. Putnam (1963) reviewed the biology and management of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae). Wallace and Sullivan (1985) reviewed the status of the white pine weevil, *Pissodes strobi* (Peck) (Coleoptera: Curculionidae).

Proverbs (1962) and Van Whervin & Wilde (1970) reported on sterile insect release for control of codling moth, however this technique falls outside of the definition used in this summary (i.e., manipulation of natural enemies) as does work with plant extracts such as that reported for neem, *Azadirachta indica* A. de Jussieu (*Meliaceae*), by Lyons et al. (1996) on the Pine False Webworm, *Acantholyda erythrocephala* (L.) (Hymenoptera: Pamphiliidae) and by Li (2000) against Balsam Fir Sawfly, *Neodiprion abietis* (Harris) (Hymenoptera: Diprionidae).

In Ontario, more than 75 species have been the subject of studies in which associated natural enemies have been documented. Introduction of exotic natural enemy species were implemented for 12 invasive alien arthropods and five exotic weeds. The contributions published in JESO on these species are varied but can be divided into broad categories, Pest Life History and Natural Enemy Complexes, General Studies of Natural Enemy Communities, Natural Enemy Biology, Classical Biological Control of Weeds, Classical Biological Control of Arthropods, and Inundative Biological Control using Pathogens. Fundamental to successful biological is correct identification of their natural enemies so taxonomic studies treating relevant species are therefore also summarized under Natural Enemy Taxonomy. The approach used here summarizes, under each of the categories mentioned above, the findings published in JESO for each species studied. The 140 full length scientific papers, scientific notes and abstracts include those that identified natural enemies (arthropods and pathogens) associated with a host species and those reporting on aspects of the biology of natural enemies of pest and beneficial species. A list of the updated names of natural enemies and known hosts published in JESO from 1952–2012 is provided in the Appendix.

**1. Pest Life History and Natural Enemy Complexes**

The development of intensive agriculture brings with it a host of species that exploit a food source that, grown in large uniform plots, provides one of the optimum conditions that contributes to exponential population increases. Fundamental to implementing successful biological control is understanding the biology of target species well and identifying which natural enemies already present in the system attack the various life stages of the host. In Ontario, numerous studies have documented the natural enemies of native and non-native species, usually in response to outbreaks in particular crops or regions. In addition to greater knowledge of pest biologies these studies have increased knowledge of their natural enemies present in Ontario. A summary of the findings published in JESO for each species follows.

**Apple Maggot**, *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae) is a native species that occurs in Ontario and Quebec (Hoffmeister 2002). Monteith (1977; 1978) studied potential predators of apple maggot, e.g., the sowbug, *Porcellio laevis* Latreille (Isopoda: Oniscidae), centipede, *Lithobius forficatus* (L.) (Lithobiomorpha: Lithobiidae), earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), and beetles, including

*Calosoma calidum* (Fabricius), *Harpalus pensylvanicus* DeGeer (Coleoptera: Carabidae), and *Staphylinus badipes* LeConte (Coleoptera: Staphylinidae), which effectively attacked and consumed apple maggot larvae. Millipedes, *Trachelipus rathkei* (Koch) (Polydesmida: Paradoxosomatidae), attacked puparia. Monteith (1978) also reported on apple maggot parasitoids, including *Diachasma mellea* (Gahan), *D. lectus* Gahan, *D. lectoides* (Gahan), *D. alloeum* (Muesebeck) and *D. ferrugineum* (Gahan) (Hymenoptera: Braconidae). Although these parasitoid species survived in wild habitats with apple and *Crataegus* spp. (*Rosaceae*), their numbers were not sufficient to migrate into and reduce apple maggot populations in managed orchards where even low numbers of this pest could not be tolerated. Poinar et al. (1978) isolated the potential pathogens, *Pseudomonas aeruginosa* (Schroeter) Migula, *Bacillus cereus* Frankland and Frankland (Bacilliaceae), and *Streptococcus* sp. (Streptococcaceae) from larvae and puparia. A nematode, *Neoaplectana* sp. (Rhabditida: Steinernematidae) was also associated with puparia. The study suggested that natural infestation by microorganisms might play an important role in regulating apple maggot populations.

**Armyworm**, *Mythimna unipuncta* (Haworth) (Lepidoptera: Noctuidae), a Nearctic species, was studied by Goble (1965) during an outbreak in 1964. The nuclear polyhedrosis virus *Betabaculovirus* sp. (*Baculoviridae*) killed 35% of larvae. Parasitoids caused an additional 25% mortality, particularly two *Apanteles* spp. (Hymenoptera: Braconidae) and other Hymenoptera (20% and 3.3% mortality, respectively) as well as Diptera (1%). *Winthemia* sp. (Diptera: Tachinidae) was abundant at one site and birds consumed large numbers of larvae. It was concluded that overall, natural control was of such magnitude that the population was likely to crash without intervention.

**Birch Leaf Edgeminer**, *Scolioneura betuleti* (Klug) (Hymenoptera: Tenthredinidae), first discovered in Ontario in 1983 near Newmarket, represented a first record for North America (Nystrom and Evans 1989). They reported 12% parasitism by three larval parasitoids, *Chrysocharis laricinellae* (Ratzeburg), *Pnigalio minio* (Walker), and *Zagrammosoma multilineatum* (Ashmead) (Hymenoptera: Eulophidae).

**Black Army Cutworm**, *Actebia fennica* (Tauscher) (Lepidoptera: Noctuidae), a Holarctic species, was studied in black spruce plantations in Newfoundland by West (1992). Parasitism levels of up to 60% were documented. *Tachinomyia panaetius* (Walker) (Diptera: Tachinidae), and *Campoletis* sp. (Hymenoptera: Ichneumonidae) were reared from larvae. *Gonia* sp. (Diptera: Tachinidae), and *Enicospilus* sp., *Ichneumon creperus* Cresson, and *Arenetra rufipes* Cresson (Hymenoptera: Ichneumonidae) were reared from pupae. The nematode, *Steinernema feltiae* (Filipjev) (Rhabiditida: Steinernematidae) also showed promise as a potential control agent. West (1992) recommended that since only *I. creperus* was known to occur in British Columbia, where black army cutworm was also a problem, relocation of the other spp. may be useful for biological control of *A. fennica* in that province.

**Cabbage Looper**, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), is an annual migrant from the southern USA. Harcourt (1963) determined that *T. ni* was significantly impacted by *Copidosoma truncatellum* (Dalman) (Hymenoptera: Encyrtidae) but less so by the polyphagous *Itoplectis conquisitor* (Say), *Stenichneumon culpator cincticornis* (Cresson) (Hymenoptera: Ichneumonidae) and *Compsilura concinnata* (Meigen) (Diptera: Tachinidae). Polyhedral virus disease frequently killed larvae. Murillo et al. (2012) studied

the larval parasitoids of *T. ni* in field tomatoes in southwestern Ontario. Nine primary parasitoids were reared from *T. ni* larvae, including an unidentified Tachinidae, *Exeristes comstockii* (Cresson) (Hymenoptera: Ichneumonidae), *Copidosoma floridanum* (Ashmead) (Hymenoptera: Encyrtidae), *Cotesia marginiventris* (Cresson), *C. plathypenae* (Muesebeck), *Meteorus* sp., and *Microplitis alaskensis* (Ashmead), one unidentified species (Hymenoptera: Braconidae), and *Euplectrus* sp. (Hymenoptera: Eulophidae). One hyperparasitoid, *Trichomalopsis viridescens* (Walsh) (Hymenoptera: Pteromalidae) was reared from *E. comstockii*, the most abundant parasitoid (17.6% and 39.2% parasitism levels in 2005 and 2006, respectively). Although common parasitoids of *T. ni* in other parts of North America, *C. floridanum* and *C. marginiventris* occurred in <2% of the host populations in Ontario. The association of *C. plathypenae* with *T. ni* was a new host record.

**Corn Aphid,** *Rhopalosiphum maidis* (Fitch) (Hemiptera: Aphididae), is an important introduced pest of corn. Foot (1974) studied the Coccinellidae (Coleoptera) community in corn fields in southwestern Ontario. He found that *Hippodamia convergens* Guérin-Méneville, *H. tredecimpunctata tibilais* (Say), and *Coleomegilla maculata lengi* Timberlake were the most abundant species. *Adalia bipunctata* (L.), *Cycloneda sanguinea* (L.), *H. parenthesis* (Say), and *Coccinella transversoguttata* Faldermann were present but either not abundant or did not occur in all years. It was concluded that coccinellid numbers overall were insufficient to control corn aphid as high populations of beetles occurred only after aphid populations peaked and had damaged the crop.

**Diamondback Moth**, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), first found in the Ottawa area in 1854, is a global pest of cole crops. Harcourt (1963) determined that native parasitoids were a major mortality factor, the most important being the larval-prepupal parasitoid *Diadegma insulare* (Cresson) (33%), the prepupal-pupal parasitoid *Diadromus subtilicornis* (Gravenhorst) (21%) (Hymenoptera: Ichneumonidae), and the larval parasitoid *Microplitis plutellae* (Muesebeck) (Hymenoptera: Braconidae). Several species were of lesser significance including, *Oomyzus sokolowskii* (Kurdjumov) (Hymenoptera: Eulophidae), *Conura albifrons* (Walsh) (Hymenoptera: Chalcididae), *Gelis tenellus* (Say), *Campoletis* sp. (Hymenoptera: Ichneumonidae), *Dibrachys microgastri* (Bouché), *Pteromalus* sp. near *phycidis* Ashmead, and *Trichomalopsis viridescens*. According to Harcourt (1963) predators and diseases did not significantly affect *P. xylostella* populations.

**European Red Mite**, *Panonychus ulmi* (Koch) (Trombidiformes: Tetranychidae), a non-native species, is a serious pest of fruit crops in Canada (Thistlewood et al. 2013). Herbert (1953) studied the predacious phytoseid mites associated with European red mite in orchards. More than nine species were collected, including *Typhlodromus tilae* Oudemans, *T. rhenanus* (Oudemans), *T. pomi* (Parrot, Hodgkiss and Shoene), *Neoseiulus fallacis* (Garman), *T. conspicuous* var. *herbertae* Nesbitt, *T. finlandicus* (Oudemans), *T. masseei* (Nesbitt), *Phytoseius macropilis* (Banks) and *Amblyseius* spp. (Trombidiformes: Phytoseiidae). Abundance and species compositions varied among locations and years. Populations were denser in the centre of orchards in spring and early summer but increased at the periphery in midsummer, then decreased as autumn approached. Cadogan and Laing (1982) surveyed apple orchards in southern Ontario for the European red mite and its predator *Balaustium putnami* Smiley (Trombidiformes: Erythraeidae). Two distinct generations of *B. putnami* occurred, the 1st generation having an abundance of larvae and the 2nd generation being dominated by nymphs and adults (motile stages). *Balaustium putnami* coexisted with

Phytoseiidae and Stigmaeiidae and fed on both *P. ulmi* and the twospotted spider mite, *Tetranychus urticae* Koch (Trombidiformes: Tetranychidae). *Balaustium putnami* was also present in orchards with low volume pesticide application regimes suggesting that spray regimes and schedules could be designed to preserve natural enemies.

**European Skipper**, *Thymelicus lineola* (Ochsenheimer) (Lepidoptera: Hesperiidae), was first collected in 1910 near London, Ontario (Pengelly 1961). He studied its biology near Bradford, Ontario in 1958. Several native parasitoid species were recovered. Parasitism of pupae was low at 4.9%, mainly by *Itoplectis conquisitor*. Also reared from pupae were *Pimpla pedalis* Cresson and *Camposcopus* sp. (Hymenoptera: Ichneumonidae). Larval parasitoids included *Meteorus hyphantriae* Riley, *Rogas* sp. and *Casinaria* sp. (Hymenoptera: Braconidae). The hyperparasitoid *Gelis* sp. (Hymenoptera: Ichneumonidae) was reared from *M. hyphantriae*. Several Tachinidae were also reared from larvae.

**Forest Tent Caterpillar**, *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae), a cyclical pest of deciduous trees, was studied by Harmsen and Rose (1984). They documented differential mortality in wet low-lying and dry higher-ground habitats. Parasitism by *Aleiodes malacosomatos* (Mason) (Hymenoptera: Braconidae) and *Phobocampe clisiocampae* (Weed) (Hymenoptera: Ichneumonidae) and predation by unspecified species were lower in the low-lying areas, likely due to limited accessibility of appropriate sites for pupation and the greater accessibility for predators offered by drier habitats.

**Goldenrod Gall Moth**, *Epiblema scudderiana* (Clemens) (Lepidoptera: Tortricidae) was the subject of a parasitoid survey by Laing and Heraty (1982) who found the primary parasitoids *Apanteles cacoeciae* Riley, *Macrocentrus pallisteri* DeGant, *Bassus binominatus* (Muesebeck) (Hymenoptera: Braconidae) and *Scambus pterophori* Ashmead (Hymenoptera: Ichneumonidae), and the hyperparasitoid *Perilampus fulvicornis* Ashmead (Hymenoptera: Perilampidae), which attacked all the primary parasitoids. Overall parasitism was 32.4% in 1978–1979, 64.4% in1979–1980, and 76.6% in 1980–1981. Parasitism by *M. pallisteri* was the major factor influencing the large annual fluctuations (19.4% in 1978–79, 57.5% in 1979–1980, and 67.5% in 1980–81) in *E. scudderiana* populations. *Perilampus fulvicornis* appeared to be an important regulator of *M. pallisteri*, preventing it from drastically reducing *E. scudderiana* populations.

**Horse and deer flies** (Diptera: Tabanidae) were the subject of natural enemy surveys in Churchill, Manitoba by James (1952). The chalcid larval-pupal parasitoid *Diglochis occidentalis* (Ashmead) (Hymenoptera: Pteromalidae) was found to parasitize 13.9% of *Tabanus* spp., including *T. affinis* Kirby and the *T. frontalis-septentrionalis* complex, and 20.8% of *Chrysops* spp., including *C. frigidus* Osten-Sacken, and *C. furcatus* Walker. Numbers of *D. occidentalis* that emerged from *Tabanus* spp. averaged 45.5 while the smaller *Chrysops* spp. yielded an average of 16.1.

**McDaniel Spider Mite**, *Tetranychus mcdanieli* McGregor, the **Apple Mite**, *Tetranychus pacificus* McGregor, and the **Clover Mite**, *Bryobia praetiosa* Koch (Trombidiformes: Tetranychidae) in Manitoba were the subject of a survey by Robinson (1952) to document their predators. The following species were collected: *Stethocorus punctum* (LeConte), *Adalia punctata* (L.) (Coleoptera: Coccinellidae), *Stilbus probatus* Casey (Coleoptera: Phalacrididae), *Orius insidiosus* (Say), *Anthocoris musculus* (Say) (Hemiptera: Anthocoridae), *Diaphnidia pellucida* Uhler, *Hyaloides harti* Knight, *H. vitripennis* (Say),

*Plagiognathus obscurus* (Uhler) (Hemiptera: Miridae), *Nabis ferus* (L.) (Hemiptera: Nabidae), *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae), *Aeolothrips melaleucus* Haliday (Thysanoptera: Aelothripidae), *Feltiella* sp. (Diptera: Cecidomyiidae), *Toxomerus geminatus* (Say) (Diptera: Syrphidae), *Chrysopa carnea* (Stephens), *C. chi* Fitch (Neuroptera: Chrysopidae), *Hemerobius simulans* Walker, *H. stigmaterus* Fitch (Neuroptera: Hemerobiidae), *Typhlodromus fallacis* (Garman), *T. longipilus* Nesbit (Megostigmata: Phytoseiidae), and *Anystis agilis* Banks (Trombidiformes: Anystidae).

**Northern Corn Rootworm**, *Diabrotica barberi* Smith and Lawrence (Coleoptera: Chysomelidae), native to North America, is a minor pest in Ontario. Tyler and Ellis (1980) studied the importance of ground beetles as its predators. Among the 26 species collected, *Pterostichus melanarius* (Illiger), *Clivina fossor* (L.), *Agonum muelleri* (Herbst), *Bembidion quadrimaculatum oppositum* Say, *Poecilus lucublandus* (Say), and *Harpalus affinis* (Schrank) (Coleoptera: Carabidae) were most numerous. Radioactive labelling trials indicated that carabids were probably more important as larval than egg predators.

**Obliquebanded Leafroller**, *Choristoneura rosaceana* (Harris), the **Eyespotted Bud Moth**, *Spilonota ocellana* (Dennis and Schiffermüller), and the **Pale Apple Budworm**, *Pseudexentera mali* Freeman (Lepidoptera: Tortricidae) all native species, were present at all sites surveyed by Hagley and Barber (1992). Although parasitism levels in unmanaged apple orchards in southern Ontario were low (4–10%), parasitoids reared included 24 species of Hymenoptera and two species of Diptera. *Itoplectis conquisitor* was the most frequently reared parasitoid from obliquebanded leafroller and pale apple budworm and *Bassus dimidiator* (Nees) (Hymenoptera: Braconidae) was most frequently reared from eyespotted bud moth. The first records of *Colpoclypeus florus* (Walker) (Hymenoptera: Eulophidae) from obliquebanded leafroller and eyespotted bud moth were reported. *Colpoclypeus florus* had earlier been introduced from Europe to control the redbanded leafroller (see below). Highest parasitism levels were found in *Coleophora* spp. (Lepidopera: Coleophoridae) (30.2%) and *Sparganothis* spp. (Lepidoptera: Tortricidae) (62%), primarily due to *Scambus* spp. and *Orgilus scaber* Muesebeck (Hymenoptera: Braconidae) in the former and *Triclistus* spp. (Hymenoptera: Ichneumonidae) in the latter.

**Pine Shoot Beetle**, *Tomicus piniperda* (L.) (Coleoptera: Curculionidae), a European species, was first found in the Niagara region in 1993 (Bright 1996). Parasitoids found in his study included *Coeloides pissodis* (Ashmead), *Spathius* sp. (Hymenoptera: Braconidae), *Dinotiscus dendroctoni* (Ashmead), *Rhopalicus tutela* (Walker), *Roptrocerus xylophagorum* (Ratzeburg) (Hymenoptera: Pteromalidae), *Eupelmus* sp. (Hymenoptera: Eupelmidae) and *Eurytoma* sp. (Hymenoptera: Eurytomidae). Predators included *Platysoma gracile* LeConte (Coleoptera: Histeridae), *Corticeus praetermissus* (Fall) (Coleoptera: Tenebrionidae), *Medetera signaticornis* (Loew) and *M. pinicola* Kowarz (Diptera: Dolichopodidae). Most of the species found are habitat-specific rather than host-specific, thus any bark beetle encountered under the bark may be a suitable host. A few parasitoid species, e.g., *Eupelmus* sp., may be hyperparasitoids. It was concluded that further investigation of the role of native natural enemies would provide evidence on whether or not there is a need to introduce exotic natural enemies.

**Potato Leafhopper**, *Empoasca fabae* Harris (Hemiptera: Cicadellidae), is a pest of a variety of field crops such as edible beans, potatoes, alfalfa, peanut and soybean (Appleton et al. 2004). They concluded that predators and parasitoids were not effective

regulators of potato leafhopper populations, despite egg parasitism up to 40% by *Anagrus armatus* (Ashmead) (Hymenoptera: Mymaridae). Although the fungus *Zoophthora radicans* (Brefeld) Batko (Entomophthoraceae) caused epizootics, the narrow environmental conditions required for this are rare in Ontario; thus it was not considered to be a reliable control.

**Redbanded Leafroller**, *Argyrotaenia velutinana* (Walker) (Lepidoptera: Tortricidae) is a native species that occurs on broad-leaved trees in eastern North America (Hikichi 1971). In response to increasing outbreaks in apple orchards in Ontario, Hikichi (1962) studied its mortality factors. *Trichogramma minutum* parasitized ~2% of the eggs collected, ~50% of larvae were infected by a granulovirus and another ~12% of larvae were parasitized by *Phytodietus vulgaris* Cresson (Hymenoptera: Ichneumonidae). The study concluded that disease and drought conditions that reduced foliage quality were the primary factors contributing to mortality of *A. velutinana*.

**Six-spotted Leafhopper**, *Macrosteles fascifrons* (Stål) (Hemiptera: Cicadellidae), is an important vector of aster-yellows virus (Miller and De Lyzer 1960). They conducted field surveys but only a single parasitoid species, *Epigonatopus plesius* Fenton (Hymenoptera: Dryinidae) was recovered from adults and levels of parasitism were not considered of economic importance.

**Soybean Aphid**, *Aphis glycines* Matsumura (Hemiptera: Aphididae), native to eastern Asia, was first reported in Ontario in 2001 (Ragsdale et al. 2004). Bahlai and Sears (2009) studied the population dynamics of soybean aphid and the predator *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in vineyards in the Niagara region. They found that high populations of *H. axyridis* were correlated with substantial numbers of soybean aphid when aphids occurred early in the season. However, outbreaks of *H. axyridis* in vineyards were observed when the numbers of soybean aphid eggs were fewest on overwintering buckthorn, *Rhamnus* spp. (*Rhamnaceae*), plant hosts. The availability of high numbers of eggs, oviposited by soybean aphid late in the season on the winter host plant, served to divert *H. axyridis* from feeding on ripening grapes in vineyards. Thus Bahlai and Sears (2009) showed that high numbers of aphids in soybean did not result in high numbers of *H. axyridis* invading vineyards. They proposed a 'kick start/distract' model to explain these dynamics and provide a basis for integrated management.

**Spotted Tentiform Leafminer**, *Phyllonorycter blancardella* (Fabricius) (Lepidoptera: Gracillariidae) an invasive alien pest from the Palaearctic is an important pest of apples in central Ontario as well as other parts of eastern Canada (Vincent et al. 2013). Johnson et al. (1977) studied the seasonal occurrence and natural enemies of this pest in Ontario apple orchards. They reported that the endoparasitic *Pholetesor ornigis* (Weed) (Hymenoptera: Braconidae) was the dominant parasitoid (up to 57% parasitism) and was well-synchronized with the 1st and 3rd host generations. *Sympiesis gordius* (Walker), *S. sericeicornis* (Nees), *Pnigalio minio* (Walker), *P. uroplatae* (Howard), *Chrysocharis nepereus* (Walker) and *Closterocerus* sp. (Hymenoptera: Eulophidae) impacted 1st and 2nd generation spotted tentiform leafminer, the first three species being most prevalent, although overall parasitism was at most 24%. Predation was not significant.

**Tarnished Plant Bug**, *Lygus lineolaris* (Palisot) (Hemiptera: Miridae) is a widespread and important pest of vegetable, fruit, greenhouse, and field crops, particularly those grown for seed (Broadbent et al. 2013). Broadbent et al. (1999) reared five parasitoid

species, including *Leiophron mellipes* (Cresson), *L. digoneutis* (Loan), *L. pseudopallipes* (Loan), *Leiophron lygivora* (Loan), and *L. rubricollis* (Thomson) (Hymenoptera: Braconidae). Mason et al. (2011) examined the effect of periodic cutting of alfalfa on parasitism of tarnished plant bug and alfalfa plant bug, *Adelphocoris lineolatus* (Goeze) (Hemiptera: Miridae) by *Leiophron* spp. Although populations of hosts and parasitoids declined in cut habitats, they did not go extinct and recolonization by adults sustained parasitoid populations.

**Trefoil Seed Chacid**, *Bruchophagus platyptera* (Walker) (Hymenoptera: Eurytomidae) is an important pest of alfalfa, clover and trefoil seed crops (Ellis and Nang'ayo 1992). These authors discovered two parasitoids, *Mesopolobus bruchophagi* (Gahan) and *Tetrastichus bruchophagi* Gahan (Hymenoptera: Pteromalidae) at levels of 8.2 and 11.0%, respectively. Parasitoids were not present in all fields and were more likely to occur in older fields. They noted that these same species occur elsewhere in North America where trefoil seed chacid is found.

**White Pine Weevil**, *Pissodis strobi* (Peck) (Coleoptera: Curculionidae), native to North America, is a major pest in pine plantations in most of Canada and the USA (Hulme and Kenis 2002). Wallace and Sullivan (1985) reviewed its biology, highlighting aspects that could be exploited to manage the pest. Among major larval and pupal mortality factors identified were the predator *Lonchaea corticis* Taylor (Diptera: Lonchaeidae) and the parasitoids *Eurytoma pissodes* Girault (Hymenoptera: Eurytomidae) and *Dolichotomitus terebrans nubilipennis* (Viereck) (Hymenoptera: Ichneumonidae).

**Willow Gall Fly**, *Rhabdopahaga strobiloides* Walsh (Diptera: Cecidomyiidae) was studied by Judd (1953). In addition to willow gall fly which induces the galls, the inquiline *Dasyneura albovittata* Walsh (Diptera: Cecidomyiidae) was reared from these galls, as was a single female sawfly, *Amauronematus* sp. (Hymenoptera: Tenthredinidae). Parasitoids reared from willow gall fly included *Copidosoma* sp., (Hymenoptera: Encyrtidae), *Tridymus* sp. (Hymenoptera: Pteromalidae), and *Torymus cecidomyae* (Walker) (Hymenoptera: Torymidae). *Leptacis* sp. (Hymenoptera: Platygasteridae), *Ceraphron* sp. (Hymenoptera: Ceraphronidae), *Tetrastichus* sp. (Hymenoptera: Eulophidae) and *Torymus* sp. were reared from cocoons of *D.albovittata*. Among the remaining parasitoids reared were *Adialytus salicaphis* (Fitch) and *Aphidius matricariae* Haliday (Hymenoptera: Braconidae), known parasitoids of aphids, and *Microgaster hospes* Marshall (Hymenoptera: Braconidae) and *Pediobius* sp. (Hymenoptera: Eulophidae), parasitoids of Lepidoptera. The hyperparasitoids *Lygocerus* sp. (Hymenoptera: Cephronidae) and *Alloxysta* sp. (Hymenoptera: Alloxystidae) were reared, probably from *A. phorodontis*.

**2. General Studies of Natural Enemy Communities**

Natural enemy surveys that are not pest specific provide a broad perspective of the complexes present in different habitats. Several studies published in JESO documented natural enemies associated with particular pests or crop systems, often to evaluate the impacts of management systems or pesticides on these communities. Other studies appear to have been opportunistic and documented natural enemies associated with host species likely encountered fortuitously during field trips focusing on other topics.

**Field crop habitats.** Ben-Ze'ev and Jaques (1990) surveyed alfalfa fields in southwestern Ontario for entomopathogens. The invasive Alfalfa Weevil, *Hypera postica*

(Gyllenhal) (Coleoptera: Curculionidae) was infected by *Erynia phytonomi* (Arthur) Humber, Ben-Ze'ev and Kenneth, *Erynia* sp. (Entomophthoraceae) and *Beauveria bassiana* (Balsamo) Vuillemin (Moniliaceae). *Conidiobolus obscurus* (Hall and Dunn) Remaudière and Keller, *C. thromboides* Dreschler (Ancylistaceae), *Entomophthora planchoniana* Cornu, *Erynia neoaphidis* Remaudière and Hennebert (Entomophthoraceae), and *Neozygites fresenii* (Thaxter) Remaudière and Keller (Neozygiotaceae) were associated with a mixed population of Pea Aphid, *Acyrthosiphon pisum* (Harris), Black Bean Aphid, *Aphis fabae* Scopoli, and the Green Peach Aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae). *Entomophthora muscae* (Cohn) Fresen (Entomophthoraceae) complex was associated with the Seedcorn Maggot, *Delia platura* (Meigen) (Diptera: Anthomyiidae). *Erynia echinospora* (Thaxter) Remaudière and Keller [or *E. dipterigena* (Thaxter) Remaudière and Keller] was associated with Lauxaniidae (Diptera). *Erynia petchii* (Ben-Ze'ev and Kenneth) was associated with the Meadow Spittlebug, *Philaenus spumarius* (L.) (Hemiptera: Cercopidae) and *Zoophthora radicans* (Brefeld) Batko was associated with the Potato Leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae) and Aphididae. The study concluded that entomopathogens have a role in natural regulation of pest insects and there is potential for their introduction (e.g., *B. bassiana* and *Erynia* spp.) to supplement other biological control agents to manage *H. postica* populations.

**Orchard habitats.** Hagley (1979) studied the effects of insecticides on natural predator populations in apple, *Malus* spp. (*Rosaceae*), orchards. *Hippodamia tridecempunctata tibialis* (Say) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) were the most abundant predators collected. *Phytocoris* sp., *Deraeocoris fasciolus* Knight and *Plagiognathus obscurus* (Uhler) (Hemiptera: Miridae) were the main true bug species encountered, and *Chrysopa oculata* (Say) (Neuroptera: Chrysopidae), *Hemerobius humulinus* (L.) (Neuroptera: Hemerobiidae), *Epiodes americanus* Wiedemann, *Allograpta obliqua* (Say) (Diptera: Syrphidae), *Cantharis* sp. and *Podabrus* spp. (Coleoptera: Cantharidae) commonly occurred. Overall, predator populations were low and insecticide treatments (phosmet and azinphosmethyl) appeared to reduce eggs and immature stages of the predators. Most adult predators collected immigrated from outside of treated areas. Thus, numbers of predators in natural areas was insufficient to provide effective control of the major pests: codling moth, apple maggot, and Plum Curculio, *Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae). Hagley (1979) concluded that augmentation of predator numbers is required when management practices use insecticides.

Woolhouse and Harmsen (1985) studied the population dynamics of the mite complex on foliage of a pesticide-free apple orchard. Over a 3-year period, population dynamics were highly variable but pest species did not reach economic thresholds. *Zetzellia mali* (Ewing) (Trombidiformes: Stigmaeiidae) and Phytoseiidae species tracked changes in prey abundance. *Zetzellia mali* was more closely linked to eriophyid rust mites, *Aculus* sp., abundance while the Phytoseiidae were linked to tetranychid, i.e., Two-spotted Spider Mite and European Red Mite, abundance. *Zetzellia mali* and Phytoseiidae were more abundant on trees nearer the orchard edge suggesting the acaricide spray programs that focus on the central parts of an orchard could be less detrimental to predator populations. They concluded that pest populations tend to be lower, sometimes by an order of magnitude, on McIntosh and Golden Delicious varieties than on Red Delicious and Empire varieties in a predator-rich environment.

**Non-crop habitats.** Laing and Welch (1963) reported feeding by adults of the predaceous fly, *Dolichopus gratus* Loew (Diptera: Dolichopodidae), on larvae of *Culex restuans* Theobald (Diptera: Culicidae). Edwards and Pengelly (1966) reported parasitism of *Bombus fervidus* (Fabricius) (Hymenoptera: Apidae) by *Melittobia chalybii* Ashmead (Hymenoptera: Eulophidae). Loan (1973) reported the first occurrence of parasitism of adult *Notoxus anchora* Hentz (Coleoptera: Anthicidae) by *Centistes agilis* (Cresson) (Hymenoptera: Braconidae); the level of parasitism was 7%.

**3. Natural Enemy Biology**

Understanding the biology of natural enemies provides guidance for the development and conservation of agents to better manage key pests. Since 1952, five JESO studies described methods to improve rearing of natural enemies useful as biological control agents while another 18 studied performance of potential biological control agents. Four other studies described the basic biology of particular natural enemies to better understand development, behaviours or species interactions. Finally, four studies looked at how particular pesticides affected the biology of natural enemies.

**Rearing of natural enemies.** Maybee (1956) described a method for rearing the exotic parasitoid *Basalys tritomus* Thomson (Hymenoptera: Diapriidae) on *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) in the laboratory. West and DeLong (1956) studied the biology of and developed a rearing method for *Zelus exsanguis* (Stål) (Hemiptera: Reduviidae), a generalist predator found in Ontario commonly found feeding on larvae of the forest tent caterpillar. They successfully reared three generations in the laboratory; cannibalism appeared to be an important consideration because it affects survival of newly hatched nymphs.

Corrigan et al. (1990) studied the pupal orientation and emergence success of *Horismenus puttleri* (Grissell) (Hymenoptera: Eulophidae), imported from Central America for biological control of Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae). Because *H. puttleri* is unable to overwinter in temperate North America, mass production for inundative releases was considered as the best option to use this agent. Location of host eggs on leaf surfaces influenced parasitoid pupal orientation and emergence. When egg masses faced down (i.e., underside of leaf) 98% of parasitoids pupated with their head down and 89% of adult *H. puttleri* emerged successfully. In contrast, when egg masses faced up (i.e., upper side of leaf) 63% of *H. puttleri* individuals faced down (head faced the leaf surface) and 66% of adult parasitoids emerged successfully.

Corrigan and Laing (1992) studied an improved method for producing small, consistent samples of hosts for presentation to the egg parasitoid, *Trichogramma minutum*. They described a new sampling strip to decrease preparation times and reduce damage to host *Ephestia kuehniella* Zeller eggs (Lepidoptera: Pyralidae). Corrigan et al. (1994) studied the feasibility of delaying emergence of *T. minutum* and subsequent effects on adult longevity and fecundity. Adult longevity of individuals reared at 16°C increased in direct proportion to the length of time they were held as pre-adults at this temperature, compared to 25°C. However, offspring production was reduced when reared at 16°C, although reproductive potential was not affected by length of time at 16°C or 12L:12D conditions. The results indicated that under the conditions studied emergence from *E. kuehniella* eggs

was not sufficiently delayed and rearing at lower temperatures (i.e., 16°C) adversely affected reproductive performance.

**Performance of biological control agents.** James (1959) studied egg development, hatching and prey consumption in several habitats by *Mantis religiosa* L. (Orthoptera: Mantidae), introduced from Europe in the early 1900s. Egg development differed among habitats but did not affect hatching. He found that prey abundance, primarily field crickets, influenced number of and size of egg masses indicating the importance of this prey for maintaining local populations of *M. religiosa*.

Loan (1964) studied the biology of *Centistes ater* (Nees) (Hymenoptera: Braconidae), an internal parasitoid of adult *Sitona* spp. (Coleoptera: Curculionidae), as a biological control agent of *S. lineellus* (Bonsdorff) in Canada. In the field, *C. excrucians* is well synchronized with the univoltine *S. lineellus*. The parasitoids overwintered as mature larvae in adult weevils, emerging the following spring in late April or May, depending on temperature, to pupate in the soil. Adult *C. ater* emerged in late June–early July when the summer-emerged adult *S. lineellus* were present.

Loan (1965) described the life cycle and development of *Leiophron mellipes* (Cresson) in five Miridae (Hemiptera) hosts in southern Ontario. Adults were present from May to September. Immature stages were found in *Labops hirtus* Knight (late May to mid-June, 20% parasitism), *Leptopterna dolobrata* (L.) (mid-May to end of June, 42% parasitism), *Adelphocoris lineolatus* (Goeze) and *A. rapidus* Say (June, 49% and 60%, respectively), and *Lygus lineolaris* (Hemiptera: Miridae) (June-July, 46% parasitism, and August-September, 12% parasitism). A single generation of *L. mellipes* occurred in each host species, although each of the two distinct generations of *L. lineolaris* were parasitized.

Griffiths (1972) studied the discrimination ability of the parasitoid *Pleolophus basizonus* (Gravenhorst) (Hymenoptera: Ichneumonidae) introduced from 1939–1949 for biological control of the invasive European Pine Sawfly, *Neodiprion sertifer* (Geoffroy) (Hymenoptera: Diprionidae). Although unable to detect hosts containing eggs of conspecifics, *P. basizonus* were able to detect hosts containing later developmental stages. *Pleolophus basizonus* was also recovered from two other introduced and seven native sawflies.

Reid and Harmsen (1975) studied the biology of *Trihabda borealis* Blake (Coleoptera: Chrysomelidae) on goldenrod, *Solidago canadensis* (Kirby) (*Asteraceae*). They determined *T. borealis* is of major importance as a phytophage on *S. canadensis* in southeastern Ontario, although serious defoliation was rare.

Ramey (1990) studied the host identification and oviposition behaviour of *Eurytoma obtusiventris* Gahan (Hymenoptera: Eurytomidae), a parasitoid of *Eurosta solidaginis* (Fitch) (Diptera: Tephritidae) that live in galls of goldenrod (*Solidago* spp.). Female *E. obtusiventris* preferred stems of *Solidago altissima* L. infested with *E. solidaginis* but also explored *S. altissima* stems without fly larvae, although females only oviposited in plants containing host larvae. He also showed that *E. obtusiventris* females prefer *S. altissima* infested plants over infested *S. canadensis* plants.

George (1979) studied the potential of *Dugesia tigrina* (Girard) (Tricladida: Duegesiidae) for control of mosquitoes in Ontario. Field tests showed that *D. tigrina* reduced populations of *Culex restuans* and *C. pipiens* L. (Diptera: Culicidae) by 17 times (4/dip versus 69/dip in control treatments). Low oxygen levels and toxins such as turpentine and paint were important mortality factors of *D. tigrina* in catch basins (George 1984).

Loan (1982) developed a field technique to study the interaction of the fungi *Zoophthora* spp. (Entomophthoraceae) and the parasitoid *Perilitus colesi* (Drea) (Hymenoptera: Braconidae) both of which attack larvae of the alfalfa weevil. Foliar applications of the fungicide captafol protected weevil larvae from attack by *Zoophthora* spp. The study confirmed earlier findings that peak attack by *M. colesi* occurred after disease epizootics caused by *Zoophthora* spp. began to subside.

Bolter and Laing (1984) studied competitive interactions between *Diadegma insulare* and *Microplitis plutellae* for larvae of diamondback moth. Development of both parasitoids was synchronized with that of the host. At 23°C average fecundity was 814 eggs per female for *D. insulare* and 316 eggs per female for *M. plutellae*. Degree-day development from egg to adult was 282 above 6.6°C for *D. insulare* and 218 above 9.2°C for *M. plutellae*. *Diadegma insulare* avoided superparasitism and multiple parasitism of larvae already parasitized by *M. plutellae*. In contrast, *M. plutellae* avoided superparasitism but could not detect eggs of *D. insulare* for at least 12 h after they were oviposited in the host. When eggs of both species were oviposited at the same time, 1st instar *M. plutellae* was intrinsically superior to 1st instar *D. insulare*. However, 2nd and 3rd instar *D. insulare* were superior to 1st instar *M. plutellae*.

Clements (1989) studied the role of the stigmaeid mite, *Z. mali* in orchards. *Zetzellia mali* fed on the European red mite and the Apple Rust Mite, *Aculus schlechtendali* (Nalepa) (Trombidiformes: Eriophyidae) but did not interfere with the phytoseiid mite *Typhlodromus caudiglans* (Schuster) (Mesostigmata: Phytoseiidae), either by intraguild predation or competition.

Whistlecraft and Lepard (1989) studied the effect of flooding on the survival of the Onion Maggot, *Delia antiqua* (Meigen) (Diptera: Anthomyiidae), and two of its parasitoids, *Aphaereta pallipes* (Say) (Hymenoptera: Braconidae) and *Aleochara bilineata* Gyllenhal (Coleoptera: Staphylinidae). Survival of *A. pallipes* was greater than or equal to that of its host while survival of *A. bilineata* was less, even at temperatures below the developmental threshold (1°C). This suggested that flooding of fields to control *D. antiqua* may lead to elimination of *A. bilineata* populations. Whitfield et al. (1981) developed a computer model to simulate the interaction between onion maggot and *A. pallipes*, a larval parasitoid. The model determined that *A. pallipes* reduced 2nd and 3rd generation maggot populations, resulting in a 70% profit gain. As well, the model provided guidance on when spray applications would least affect parasitoids.

Wang and Laing (1989) studied the reproductive biology of the introduced *Ageniaspis testaceipes* (Ratzeburg) (Hymenoptera: Encyrtidae), an egg-larval parasitoid, and its effect on the spotted tentiform leafminer. Potential fecundity of *H. testaceipes* was 25 eggs per female and an average of 9.1±3.4 broods were produced over an average lifespan of 7.5±2.7 days. Although newly oviposited host eggs were preferred, eggs up to 5 days old were successfully parasitized and parasitoid development took 35–37 days at 25°C. Development of parasitized *H. testaceipes* was delayed and these individuals were larger than unparasitized individuals. The longer feeding period and larger size of parasitized spotted tentiform leafminer larvae suggest that *H. testaceipes* may consume more foliage, however, this may also increase the size and/or number of parasitoids. They concluded that the attribute that female *H. testaceipes* may oviposit into host eggs of any age provides a

larger window of opportunity for oviposition, facilitating synchronization with its host and improve efforts to establish *H. testaceipes* in North America.

Song (1990) studied the potential for *Gelis tenellus*, a hyperparasitoid, to influence parasitism of gypsy moth by *Cotesia melanoscela* (Ratzeburg) (Hymenoptera: Braconidae). *Gelis tenellus* produced significantly more eggs when hosts were available on a daily basis versus every third day. Nealis and Bourchier (1995) compared the vulnerability to hyperparasitism of different European and Asian strains of *Cotesia melanoscela*, a biological control agent of gypsy moth. Rates of predation and hyperparasitism were not related to cocoon morphology but were dependent on length of time cocoons were exposed to hyperparasitism in the field. The nondiapause characteristics of the Asian strain decreased its exposure time and therefore reduced vulnerability to hyperparasitism. Thus, inundative releases of nondiapause strains early in the season were likely to minimize exposure of *C. melanoscela* to hyperparasitism, which currently is 95% over the summer. They also concluded that diapause of already established local strains of *C. melanoscela* could be manipulated by varying photoperiod during larval development, thus release of additional exotic strains would not be required.

Villaneuva and Harmsen (1996) studied the ecological interactions of tarsonemid mites in apple orchards. *Dendroptus* n. sp. near *suskii* Sharonov and Livshitz (Trombidiformes: Tarsonemidae) was identified as a predator of apple rust mite and contributed to the mid-summer decrease of this pest.

Jones et al. (2006) studied the influence of greenhouse microclimate on predation of Western Flower Thrips, *Franklinella occidentalis* (Pergande) (Thysanoptera: Thripidae) by *Neoseiulus cucumeris* (Oudemans) (Mesostigmata: Phytoseiidae). Leaf temperature was positively correlated with predation and oviposition by *N. cucumeris*, suggesting that seasonal adjustments in release of this biological control agent could be made.

**Development, behaviour and species interactions.** Vander Hoek (1971) described the larval instars of *Aphidius nigripes* Ashmead (Hymenoptera: Braconidae), a common parasitoid of the pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae). Five instars were documented based on changes in cuticular structure observed at 24 h intervals.

Bennett (2004) studied the host location behaviour of *Pelecinus polyturator* (Drury) (Hymenoptera: Pelecinidae) a common endoparasitoid of june beetles, *Phyllophaga* spp. (Coleoptera: Scarabeidae). Host location consisted of wandering on the surface until the antennae ceased moving and the distal abdominal segments appeared to touch the surface. Then a series of movements would push the distal segment into the soil, penetrating up to 5 cm. The procedure lasted about 145 seconds.

Macfarlane and Pengelly (1978) studied *Brachioma* spp. (Diptera: Sarchophagidae), and the eulophid *Melittobia chalybii* Ashmead (Hymenoptera: Eulophidae), parasites of the brood of *Bombus* spp. in southern Ontario. They reported *Brachioma setosa* Coquillett as a parasite of *Bombus* for the first time and found that 2–3 generations occurred each season. As well, *M. chalybii* attacked both *Bombus* spp. and *B. setosa*. They found that these parasites attacked larvae of *Bombus* spp. and infested colonies had fewer workers and died out more quickly than unparasitized colonies.

Wright and Laing (1979) reported on the effects of temperature on development, adult longevity and fecundity of *Coleomegilla maculata lengi* Timberlake (Coleoptera:

Coccinellidae) and its parasitoid *Dinocampus coccinellae* (Shrank) (Hymenoptera: Braconidae). A total of 198.8 degree-days (above 13.8°C) were required for development of *C. maculata lengi* from egg to adult while 180.5 degree-days (above 11.2°C) were required for *D. coccinellae* development. *Coleomegilla maculata lengi* produced an average of 191.5 eggs per female and longevity averaged 82.3 days. *Dinocampus coccinellae* survived for 5 days when continuously exposed to hosts and produced an average of 66.8 eggs per female at 25°C. Earlier studies had estimated potential fecundity of *D. coccinellae* at 200–400 eggs per female, thus it appeared that realized fecundity was limited by the ability of females to find hosts. Wright (1979) observed the copulatory behaviour of *C. maculata lengi*. The male mounted females from behind and assumed the dorsal position as is normal for braconids. Copulation lasted for 18–20 min, considerable longer than the <1 min known for other braconids.

**Effects of pesticides on natural enemies.** Robinson (1953) described the biology of *Stethorus punctum* (LeConte) (Coleoptera: Carabidae) and determined that DDT and methoxychlor were lethal to adults, killing 47.1 and 60%, respectively, in laboratory experiments. Fisher (1988) reported on the effects of pesticides on *Pholetesor ornigis* (Weed) and *P. pedias* (Nixon) (Hymenoptera: Braconidae), parasitoids of the spotted tentiform leafminer. The number of days to 50% mortality (LT50) of *Pholetesor pedias* was higher than for *P. ornigis* when exposed to azinphosmethyl and permethrin.

Hagley and Laing (1989) studied the effect of pesticides on parasitism by *T. minutum* and *T. pretiosum* Riley (Hymenoptera: Trichogrammatidae) of eggs of codling moth. The insecticides azinphosmethyl, difluibenzuron, permethrin, and methomyl were toxic, as was the acaricide cyhexatin. Triflumuron, a lower rate of diflubenzuron (1/3 of recommended dose), and the fungicides captan, dodine and polyram did not affect parasitism.

Wang and Laing (1990) studied the toxicity of methomyl, permethrin, azinphosmethyl and phosmet to adult *Ageniaspis testaceipes*, an introduced egg-larval parasitoid of the spotted tentiform leafminer. At the time, these insecticides were used to control spotted tentiform leafminer, the plum curculio, codling moth and apple maggot in Ontario orchards. They concluded that understanding tolerance levels of *A. testaceipes* to pesticides used is essential for integrating this biological control agent into management programmes. For example, methomyl and permethrin residues caused higher mortality of *A. testaceipes* than azinphosmethyl and phosmet, although responses of individual females were highly variable to the latter two products.

## 4. Classical Biological Control of Weeds

Studies on classical biological control of weeds reported in JESO have been few and none are comprehensive. A great deal of the work in this area relevant to Ontario has been published elsewhere (e.g., The Canadian Entomologist). In JESO there are publications on various aspects of exotic phytophagous-feeding insects introduced for biological control of five non-native weed species (Table 1). Three species are on the Noxious Weeds in Ontario list (Anonymous 2013) and all are treated in the *Ontario Weeds* guide (Alex, 1998). The publications summarized here report on the status, at the time of publication, of introduced species.

**Canada Thistle**, *Cirsium arvense* (L.) Scopoli (*Asteraceae*), is a noxious and widespread weed in Ontario, most abundant in southern areas (Moore, 1975). *Urophora*

*cardui* L. (Diptera: Tephritidae) was introduced for its biological control (Laing 1978). Three years after initial releases in 1975, 40% of host plants around the release site contained galls of *U. cardui* and the agent had spread to plants several hundred meters from the release site.

**Leafy Spurge**, *Euphorbia esula* L. (*Euphorbiaceae*), is a noxious and widespread weed in Ontario (Best et al. 1980). LeSage (1996a) reported that populations of the introduced biological control agent, *Aphthona nigriscutis* Foudras (Coleoptera: Chrysomelidae) increased significantly in 1994 and 1995 but did not damage leafy spurge. The survey also yielded specimens of *A. flava* Guillebeau, a related exotic species that had not been approved for release, suggesting that some individuals in the released population were misidentified.

**Nodding Thistle**, *Carduus nutans* L. (*Asteraceae*), is a noxious and widespread weed in Ontario where it is most abundant, although it occurs throughout Canada (Desrochers et al. 1988). Laing and Heels (1979) reported that three years after 1975 releases, *Rhinocyllus conicus* Frölich (Coleoptera: Curculionidae) was well established around Guelph. Infestation levels up to 95% (24–95%) were recorded. Thistle seed heads with 7+ pupal cells of *R. conicus* produced significantly reduced amounts of seed than those seed heads with 0–6 pupal cells.

**Purple Loosestrife**, *Lythrum salicaria* L. (*Lythraceae*), is highly abundant in the Great Lakes Basin and along the St. Lawrence River (Mal et al. 1992). Corrigan et al. (1998) conducted a study on potential non-target feeding by *Neogalerucella calmariensis* (L.) (Coleoptera: Chrysomelidae) introduced for biological control of this invasive plant. The study was initiated based on the field observations of *G. calmariensis* feeding on cuttings of Swamp Loosestrife, *Decodon verticillatus* (L.) Elliott, and egg masses on Winged Loosestrife, *Lythrum alatum* Pursh (*Lythraceae*), at the Ontario Royal Botanical Garden where large populations of *N. calmariensis* were present. Monitoring of all three plant species through two generations of the beetle revealed that *L. salicaria* plants sustained moderate to complete defoliation in all areas monitored. Several *D. verticillatus* and *L. alatum* plants were slightly damaged by *N. calmariensis* feeding and about 15 egg masses were found when several hundred of these non-target plants were examined. No late instar larvae were found on either *D. verticillatus* or *L. alatum*. The results suggested that the minimal feeding and few egg masses represent a 'spill-over' effect that occurred when large numbers of *N. calmariensis* were dispersing from locations where *L. salicaria* populations had been significantly reduced.

**St. John's Wort**, *Hypericum perforatum* L. (*Hyperiaceae*) is found in the Great Lakes-St. Lawrence regions of Ontario (Crompton et al. 1988). LeSage (1996b) reported on the presence in the Gatineau area of Quebec of *Chrysolina hyperici* (Förster) (Coleoptera: Chrysomelidae), introduced for biological control of St. John's wort. The agent had dispersed 145 km from the release site in Belleville, Ontario, at an estimated rate of 6 km per year.

**5. Classical Biological Control of Arthropods**

Introduction of exotic species for the biological control of arthropods has been reported in JESO for 15 invasive species (Table 2). All but one of these papers (Maxwell and Morgan 1952) treated pests of agriculture crops or trees in Ontario. The JESO studies summarized here for each target species report on the status of introduced biological

control agents, i.e., whether established or not, and document native natural enemy species associated with the targets at the time of publication.

**Alfalfa Blotch Leafminer**, *Agromyza frontella* (Rondani) (Diptera: Agromyzidae), invaded Ontario in the mid 1970s. Coote and Ellis (1987) studied the parasitoids of alfalfa blotch leafminer near Guelph in 1983–1984. Four parasitoids, *Diglyphus begini* (Ashmead), *D. intermedius* (Girault), *D. pulchripes* (Crawford) and *Pnigalio maculipes* (Crawford) (Hymenoptera: Eulophidae) were reared from larvae. *Cyrtogaster vulgaris* Walker (Hymenoptera: Pteromalidae) and *Chrysocharis giraulti* Yoshimoto (Hymenoptera: Eulophidae) were reared from pupae. Overall parasitism was low, averaging 3.4% due in part to poor synchrony of the parasitoids with the host. One additional species, *Diglyphus isaea* (Walker) (Hymenoptera: Eulophidae) was collected from alfalfa plants. Parasitoids emerged later in the spring than alfalfa blotch leafminer, thus parasitizing only 2nd and 3rd generation hosts. *Diglyphus intermedius* was the most abundant of the larval parasitoids and the three *Diglyphus* spp. accounted for 75% of the parasitoids reared from hosts. *Diglyphus isaea* and *C. vulgaris* are exotic parasitoids and were reported for the first time in Ontario and in association with alfalfa blotch leafminer. All but one of the pupal parasitoids was *C. vulgaris* and parasitism levels were low, averaging <1% but were highest at 3.3% in the 3rd generation, although sampling included only the few pupae on plants and not those in soil where alfalfa blotch leafminer normally pupates. It was concluded that the existing parasitoid complex was unlikely to maintain alfalfa blotch leafminer below economic thresholds and exotic species already established in the USA would be suitable for introduction. Harcourt et al. (1987) reported that the European larval-pupal endoparasitoid *Dacnusa dryas* (Nixon) (Hymenoptera: Braconidae), first released in1979 near Ottawa, became well established in most counties of southern Ontario, with rates of attack averaging 84% (65–95%). Dispersal from nursery plots and natural spread from release sites and life table data indicated that alfalfa blotch leafminer populations declined less than three years after release of *D. dryas*.

**Alfalfa Weevil**, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), of European origin, was first reported in the Great Lakes region in the early 1960s. Abu and Ellis (1976) studied *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae) a larval parasitoid of alfalfa weevil and found that although spring emergence of *B. curculionis* was synchronized with that of alfalfa weevil larvae, parasitism levels were low early in the season (6.3–33.3%) when host populations were highest, increasing later in the season (60–68%) when host populations were declining. High rates of diapause in 1st generation parasitoid larvae were thought to be responsible for the lower initial parasitism. Several hyperparasitoids, *Gelis* sp., *Trichomalopsis viridescens*, *Pteromalus* sp. and *Eupelmella vesicularis* (Retzius) (Hymenoptera: Eupelmidae) were reared from 24% of *B. cuculionis*. Harcourt et al. (1980) studied the distribution of the European exotic *Perilitus aethiops* Nees (Hymenoptera: Braconidae), a parasitoid that attacks adults of alfalfa weevil. First released in Ontario in 1970–1971, *P. aethiops* became widely established in southern Ontario by 1979, where parasitism levels of the spring generation of alfalfa weevil averaged 60% (13–92%). Harcourt et al. (1982) conducted a survey for *Perilitus colesei* (Drea), a larval parasitoid introduced in 1970 and found that *P. colesi* was present in 39 of 41 counties, with parasitism levels averaging 13% (1–52%). Although two fungal pathogens also attack alfalfa weevil larvae, *M. colesi* emerges from cocoons in late May or early June and attacks larger

host larvae, likely after epizootics have subsided and therefore it is able to coexist with the disease agents. The widespread distribution of *M. colesi* is probably the result of dispersal from the USA into southwestern Ontario and dispersal from the release site in Prince Edward County in eastern Ontario. Harcourt and Ellis (1992) determined that the larval parasitoid *Bathyplectes anurus* (Thomson) (Hymenoptera: Ichneumonidae), introduced in 1970, had become widespread in southern Ontario and had displaced *B. curculionis* as the main larval parasitoid of *H. postica*. Abundance of this parasitoid was influenced by the fungal pathogen *Zoophthora phytonomi* (Arthur) Batko (Entomophthoraceae), which dominated during wet periods while *B. anurus* increased during successive dry springs.

**Carrot Rust Fly**, *Psila rosae* (Fabricius) (Diptera: Psilidae) was introduced around 1885. Releases of *Chorebus posticus* (Haliday) (Hymenoptera: Braconidae), a larval parasitoid, and *Basalys tritoma*, a pupal parasitoid, were made from 1949–1953 in Ontario, British Columbia, and Prince Edward Island (Maybee 1954). Although recoveries were made in the year of release neither *C. posticus* nor *B. tritoma* were collected the following winter.

**Cereal Leaf Beetle**, *Oulema melanopus* (L.), (Coleoptera: Chrysomelidae), was first found in southwestern Ontario in 1965 and became established in 1967 (McClanahan et al. 1968; Bierne 1971). McClanahan *et al.* (1968) reported that while no natural enemies were present in southwestern Ontario during the study, predators, parasitoids and diseases had been reported elsewhere in parts of North America invaded by this European pest. Ellis et al. (1979) reported that *Tetrastichus julis* (Walker) (Hymenoptera: Eulophidae), introduced into southern Ontario in 1974 as a biological control agent for cereal leaf beetle, had by 1977 expanded its range into the area north of Lake Huron and parasitism levels from 19–90% were documented. In areas where *T. julis* had been established since 1976, parasitism averaged 65%, indicating that it can maintain populations even when host densities are low. This successful biological control continued until an outbreak occurred in the central tobacco growing area of Ontario (Ellis et al. 1989). In a 1987 survey they reared a single *Anaphes* sp. from eggs of cereal leaf beetle and parasitism by *T. julis* was nil, despite high levels (~75%) of parasitism in other parts of the province. It was concluded that tillage, which kills 95% of overwintering *T. julis*, probably accounted for the absence of this agent in areas where crop rotations were practiced.

**Codling Moth**, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), of southeastern European origin, was present in Ontario by 1858–1860 and a major apple pest by 1868 (Putnam 1963). In a review of the status of *C. pomonella* Putnam (1963) included what was known at the time about natural enemies. *Trichogramma minutum* was the only egg parasitoid associated with *C. pomonella*, while larval parasitoids included *Scambus pterophori* Ashmead (Hymenoptera: Ichneumonidae), *Dibrachys microgastri* (Bouché) (Hymenoptera: Pteromalidae), *Hymenochaonia delicata* (Cresson), *Macrocentrus ancylivora* Rohwer, *M. instabilis* Muesebeck, *Phanerotoma fasciata* Provancher (Hymenoptera: Braconidae), *Mastrus carpocapsae* (Cushman), *Temelucha minor* (Cushman), *Cryptus albitarsis* (Cresson), *Glypta* sp., *Aritranis* sp. (Hymenoptera: Ichneumonidae), and the adventive *Ascogaster quadridentata* Wesmael (Hymenoptera: Braconidae). *Dibrachys microgastri* was also found to be a hyperparasitoid of *A. quadridentata* as were *Perilampus fulvicornis* Ashmead, *P. tristis* Mayr and *Perilampus* sp. (Hymenoptera: Perilampidae), sometimes at levels of 72%. Pupal parasitism was negligible but included *D. microgastri*, *Eupelmus*

*cyaniceps* Ashmead (Hymenoptera: Eupelmidae), *Pimpla annulipes* Brullé, *Itoplectis conquisitor*, and *Eurytoma* sp. a hyperparasitoid. *Eupelmus cyaniceps* also parasitized the larval parasitoids *Macrocentrus* spp. and the pupal parasitoid *P. annulipes*. *Liotryphon caudatus* (Ratzeburg) and *Nippocryptus vittatorius* (Jurine) (Hymenoptera: Ichneumonidae) were introduced from France from 1941–1945 but failed to establish. *Elodia tragica* (Meigen) (Diptera: Tachinidae) and *Pristomerus vulnerator* (Panzer) (Hymenoptera: Ichneumonidae) were introduced from England in 1943–1944. *Ascogaster quadridentata, L. caudatus* and *N. vittatorius* were introduced into British Columbia but only *A. quadridentata* became established. The most important insect predators were the trogositid borer *Tenebroides corticalis* Melsheimer (Coleoptera: Trogossitidae), *Chrysopa carnea* (Stephens) and *C. rufilabris* Burmeister (Neuroptera: Chrysopidae), the egg feeding *Haplothrips faurei* Hood and *Leptothrips mali* (Fitch) (Thysanoptera: Phlaeothripidae), and the mite *Anystis agilis* Banks (Trombidiformes: Anystidae). Downy, *Dendrocopos pubescens* (L.), and hairy, *D. villosus* (L.) woodpeckers (Piciformes: Picidae) were important predators of codling moth. Several diseases have been isolated from codling moth, including *Bacillus cereus* from the Niagara Penninsula, *Beauveria bassiana* from Nova Scotia, and *Hirsutella subulata* Petch (Ophiocordycipitaceae) from the USA. *Mermis* sp. and *Neoaplectana* n. sp. (DD136) (Mermithidae) nematodes were also found infecting codling moth. Hagley (1970) studied codling moth to assess the importance of biotic and abiotic factors in regulating populations. He determined that disease (34.4–65.1%) and parasitism (31.9–80%) could be significant, although they were not uniform across orchards. Predation by birds was as high as 90%. Hagley (1987) surveyed the *Trichogramma* spp. in apple orchards in southern Ontario after inundative releases of *T. pretiosum* and *T. minutum*. Only *T. pretiosum* was recovered from sentinel codling moth eggs set out in 1982 and 1983. Parasitism ranged from 2.2–11.9% and parasitoids were recovered in both unsprayed and sprayed orchards. In 1984, *T. minutum* was the only species recovered in unsprayed orchards. The results indicated that *Trichogramma* spp. migrated into orchards from alternative hosts and occurred in low numbers early in the season. This and overall low natural parasitism suggested that augmentative releases and management of parasitoid populations could improve the success of biological control of coding moth.

**Cranberry Fruitworm**, *Acrobasis vaccinii* Riley (Lepidoptera: Pyralidae), in New Brunswick was the subject of a study showing that eggs were parasitized by *Phanerotoma franklini* Gahan (Hymenoptera: Braconidae) and that *Cryptus albitarsus albitarsus* (Cresson) (Hymenoptera: Ichneumonidae) emerged from overwintered larvae (Maxwell and Morgan 1952).

**European Pine Shoot Moth**, *Rhyacionia buoliana* (Denis and Schiffermüller) (Lepidoptera: Tortricidae), was introduced adventively from the USA into Ontario near Windsor in 1925 (Pointing and Green 1962). Coppel and Arthur (1954) provided an update on parasitoids introduced in Ontario to control it. From1928–1953 nine species, including *Campoplex difformis* (Gmelin), *Sinophorus turionum* (Ratzeburg), *Temeluca interruptor* (Gravenhorst), *Exeristes ruficollis* (Gravenhorst), *Pimpla turionellae* (L.), an unidentified *Pimpla* sp. (Hymenoptera: Ichneumonidae), *Orgilus obscurator* (Nees) (Hymeoptera: Braconidae), *Copidosoma filicorne* (Dalmen) (Hymenoptera: Encyrtidae), and *Baryscapus turionum* (Hartig) (Hymenoptera: Eulophidae) were released. Among the species recovered during post-release surveys, *C. interruptor* and *O. obscurator* accounted for more than 2/3

of all parasitoids. Overall parasitism was 1.96–10.86% and the native species, *Campoplex* sp., *Itoplectis conquisitor*, *Itoplectis* sp., *Scambus hispae* (Harris) (Hymenoptera: Ichneumonidae), *Eurytoma appendigaster* (Swederus) (Hymenoptera: Eurytomidae), *Habrocytus* sp. (Hymenoptera: Pteromalidae), *Hyssopus thymus* Girault (Hymenoptera: Eulophidae), the tachinid *Exeristes comstockii*, and an undetermined species were reared from European pine shoot moth. Individuals of the introduced *T. turionum*, *C. difformis*, and *P. turionellae* were also reared; however, no recoveries of *C. geniculatum*, *C. rufifemur* and *E. ruficollis* were made during the survey. Pointing and Green (1962) determined that the 21 native and introduced parasitoids had negligible impact on the host and only four, *O. obscurator*, *T. interruptor*, *P. turionellae* and *B. turionum*, of the 13 species introduced had established. Among these, *O. obscurator* was the most abundant in Ontario and Quebec.

**Gypsy Moth**, *Lymantria dispar* (L.) (Lepidoptera: Erebidae), was first reported in Ontario on Wolf Island near Kingston in 1969, spreading to the mainland and throughout eastern Ontario by 1971 (Griffiths 1977). A survey in 1974–1975 by Griffiths (1977) reported that among the four parasitoid species recovered, *Cotesia melanoscela*, *Compsilura concinnata* and *Parasetigena agilis* (Robineau-Desvoidy) (Diptera: Tachinidae) are exotic introductions, none of which targeted gypsy moth, while *Pimpla pedalis* Cresson (Hymenoptera: Ichneumonidae) is native. Also reported was the native *Gelis tenellus* as a hyperparasitoid of *C. melanoscela*. *Cotesia melanoscela* was the most widely distributed while *C. concinnata* was the most abundant. Nealis and Quednau (1996) documented releases and overwintering survival of the European *Ceranthia samarensis* (Villeneuve) (Diptera: Tachinidae) introduced for biological control of gypsy moth. Releases of gravid female adults, parasitized larvae and parasitized pupae were made from 1991–1996. In each year of release, evidence of successful parasitism by field-released females was observed. All progeny retrieved were in diapause and overwintering studies indicated that survival of pharate adults was expected to be high. Because of the low fecundity of *C. samarensis* ongoing monitoring was recommended to determine if successful establishment had occurred.

**Imported Cabbageworm**, *Pieris rapae* (L.) (Lepidoptera: Pieridae), was first reported in eastern Ontario in 1871 and throughout southwestern Ontario by 1876 (Harcourt 1963). Parasitoids are important mortality factors of *P. rapae* (Harcourt 1963), principally *Cotesia glomerata* (L.) (Hymenoptera: Braconidae) which attacks larvae. Later instars are attacked by *Phryxe vulgaris* (Fallén) (Diptera: Tachinidae) and pupae are attacked by *Pteromalus puparum* (L.) (Hymenoptera: Pteromalidae). Generalist species associated with *P. rapae* include *C. concinnata*, *Helicobia rapax* (Walker) (Diptera: Sarcophagidae) and *Madremyia saundersii* (Williston) (Diptera: Tachinidae). Although invertebrate predators and birds are present they did not have a significant impact, unlike granulosis virus which caused up to 94% mortality. Corrigan (1983) conducted a survey for *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) introduced from British Columbia as a biological control agent. Recovery of *C. rubecula* near Ottawa 10 years after its release indicated that this agent had established in eastern Canada and was tolerant of winter conditions. Up to 1982, no progeny of *C. rubecula* released near Guelph and Harrow in 1978–1979 were recovered in the years after release and it was thought that *C. rubecula* had been negatively impacted by hyperparasitoids. Carter and Laing (1997) reported on recoveries of a Chinese strain of *C. rubecula* released in 1991–1992. Three years after releases *C. rubecula* was

found in the release area, although the hyperparasitoids *Catolaccus* sp. (Hymenoptera: Pteromalidae), *Mesochorus vittator* (Zetterstedt) (Hymenoptera: Ichneumonidae) and *Baryscapus galactopus* (Ratzeburg) (Hymenoptera: Eulophidae) were reared from *C. rubecula* cocoons. Parasitism levels ranged from 15–21%.

**Larch Casebearer**, *Coleophora laricella* (Hübner) (Lepidoptera: Coleophoridae), was introduced into Ontario from 1935–1941. Graham (1958) studied the effectiveness of parasitoids of larch casebearer and confirmed establishment of *Chrysocharis laricinellae* (Ratzeburg) (Hymenoptera: Eulophidae) and *Agathis pumila* (Ratzeburg) (Hymenoptera: Braconidae). Parasitism by the widely established *A. pumila* ranged from 41% south of 43° north latitude to 67% between 44–45° north and it was present in areas of low and discontinuous host populations. In contrast, *C. laricinellae* had spread only 42 miles from the release point and spread appeared to be dependent on high host populations.

**Oriental Fruit Moth**, *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae), was first reported in Ontario in 1925 (McLeod 1962). Boyce and Dustan (1954) compared parasitism of *G. molesta* in a young peach orchard and a mature orchard, before and after pesticides (DDT and parathion) came into use. The most prevalent parasitoids recovered were the introduced *Macrocentrus ancylivora*, and the native *Hymenochaonia delicata*, *Enytus obliteratus* (Cresson), *Glypta rufiscutellaris* Cresson (Hymenoptera: Ichneumonidae) and *Temelucha minor*. Overall, *M. ancylivora* populations increased since insecticide use began while those of *G. rufiscutellaris* and *H. obliteratus* decreased. *Hymenochaonia delicata* a common parasite of the ragweed borer, *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae), continued to be abundant. Dustan and Boyce (1966) assessed parasitism of *G. molesta* from 1956–1965 and found that average parasitism by *M. ancylivora* was 43.2–64.5% in 1st and 2nd generations, respectively, in the Niagara region and 10.3 and 12.4% in the Essex county region. Parasitism of 2nd generation oriental fruit moth by *G. rufiscutellaris* was 1.4% in Niagara and 28.6% in Essex. Among the other parasitoids, *T. minor* was reared from larvae of the 1st and 2nd generations, and *Enytus obliteratus* (Cresson) (Hymenoptera: Ichneumonidae) and *H. delicata* were reared from larvae of the 1st generation. The abundance of *M. ancylivora* in the Niagara region was attributed to the presence of strawberry plantings which support populations of *Ancylis comptana* (Frölich) (Lepidoptera: Tortricidae), an alternate host of *M. ancylivora*. Phillips (1969) found that *M. ancylivora* was the most abundant of eight parasitoids reared from Oriental fruit moth in pear orchards. Between 40 and 50% of 1st and 2nd generation fruit moth larvae were parasitized from 1964–1966. In 1967, parasitism of 1st and 2nd generation fruit moth larvae increased to 61–74%, respectively, a positive response to increasing host numbers. Increased parasitism of 2nd generation larvae led to low adult emergence.

**Pea Aphid**, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae), an invasive species believed to be of Palaearctic-Oriental origin, was first reported in the Ottawa area about 1898 (Mackauer 1971). Mackauer and Bisdee (1965) reported on the status of *Aphidius smithi* Sharma and Subba Rao (Hymenoptera: Aphidiidae) introduced to control pea aphid. Their southern Ontario survey revealed *Praon pequodorum* Viereck and *Aphidius nigripes* Ashmead (Hymenoptera: Aphidiidae) to be the principal parasitoids of *A. pisum*, with *Praon* sp. and *Aphelinus semiflavus* Howard (Hymenoptera: Aphelinidae) of secondary importance. Although not released in Ontario, *A. smithii* was found in areas adjacent to

Lake Ontario and it was concluded that the populations present were the result of dispersal from releases made in the USA (New Jersey, Delaware, Pennsylvania) in the late 1950s.

**Pear Psylla**, *Cacopsylla pyricola* (Förster) (Hemiptera: Psyllidae), a European invader was first reported in Ontario in 1894 (McMullen 1971). Wilde (1965) studied the biology of *C. pyricola* and noted that the nymphal parasitoid *Trechnites insidiosus* (Crawford) (Hymenoptera: Encyrtidae) was abundant before the widespread use of insecticides came to dominate control strategies. However, the predators *Chrysopa* spp., *Hippodamia* sp., *Cycloneda* sp., *Ceratomegilla* sp., *Anthocoris* sp. and *Orius* sp. were abundant during the study period. *Anthocoris melanocerus* Reuter (Hemiptera: Anthocoridae) from British Columbia was released in southwestern Ontario (Wilde 1965). Philogene and Chang (1979) reported new records of parasitic chalcidoids of pear psylla in Ontario. *Trechnites insidiosus*, *Pachyneuron* sp. and *Coccidencyrtus* sp. were found for the first time parasitizing *C. pyricola*.

**Potato Stem Borer**, *Hydraecia micacea* (Esper) (Lepidoptera: Noctuidae), an invasive pest of European origin, established in southern Ontario in the 1960s, becoming a pest in eastern Ontario in 1968 (Deedat et al. 1983). West et al. (1984) studied the parasitoids of *H. micacea*, in southern Ontario and Europe. In Ontario, the tachinid *Lydella radicis* (Townsend) (Diptera: Tachinidae) was reared from 61% of the host larvae collected. Other parasitoids recovered were *Diadegma* sp., *Campoletis* sp., *Glypta* sp., and *Pterocormis* sp. and *Therion* sp. (Hymenoptera: Ichneumonidae), although parasitism levels were low (0.5–6%). European parasitoids imported into quarantine included *Lydella stabulans* (Meigen) (Diptera: Tachinidae), *Macrocentrus blandus* Eady and Clark (Hymenoptera: Braconidae), *Exephanes occupator* Gravenhorst (Hymenoptera: Ichneumonidae) and an unidentified mermithid nematode. Comparison of the biologies of *L. radicis* and *L. stabulens* suggested that these species may coexist in the field. *Lydella stabulens* has a lower developmental threshold (6.7°C) and develops faster (159 Degree days) than *L. radicis* (13.5 °C and 113 Degree days), suggesting that the latter species would attack overwintering potato stem borer larvae earlier in the season than the former species. Developmental studies of *M. blandus* suggested that it may require an alternate host in order to produce a 2nd generation in summer. Small numbers of *L. stabulans* and *M. blandus* were released near Guelph (43.7167°N 80.4000°W).

**Red Clover Casebearer**, *Coleophora deauratella* Lienig and Zeller (Lepidoptera: Coleophoridae), was discovered in Ontario in 1989 at New Liskard (Ellis and Bjornson 1996). This European native is a threat to red clover, *Trifolium pratense* L. (*Fabaceae*), seed crops. Ellis and Bjornson (1996) studied the biology and biological control of red clover casebearer. Based on a successful biological control program in New Zealand, individuals of the European native *Neochrysocharis formosus* (Westwood) (Hymenoptera: Eulophidae) were imported from the population established in New Zealand and released in Ontario. However, no recoveries of *N. formosa* were made, although several other parasitoids, including the native *Bracon pygmaeus* Provancher (Hymenoptera: Braconidae), were reared. There are some taxonomic issues relating to whether the New Zealand specimens released in Ontario were indeed *N. formosa*, known to be Holarctic, or a distinct more host-specific population of *N. formosa*, or the related European *N. trifolii* Erdös (Hymenoptera: Eulophidae).

**6. Inundative Biological Control of Arthropods with Pathogens**

Entomopathogens, like other natural enemies, are important agents for reducing populations of pest arthropods, particularly insects. Among these, *Bacillus thuringiensis* Berliner (Bacilliaceae) is the most studied and this is evident in the JESO publications summarized here. In addition, papers in JESO have evaluated several other entomopathogenic organisms for their potential for inundative biological of pest insects (Table 3).

Cameron (1952) conducted a review of diseases of insects to 1951. Included was information on the fungi, *Beauveria bassiana*, *Anisoplia austraca* Herbst, *Metarhizium anisopliae* (Metchnikoff) Sorokin (Clavicipitaeae), *Aspergillus flavus* Link (Trichocomaceae) and *Isaria larinosa* (Holmskiold) Fries (Moniliaceae), the bacteria *Enterobacter aerogenes* Hormaeche and Edwards, *Bacillus subtilis* (Ehrenberg), *B. proteus* (Bach), *B. thuringiensis*, and *Paenibacillus popilliae* Dutkey (Bacilliaceae), as well as polyhedroviruses and granuloviruses. The main conclusion was that better understanding of the biology and pathogenesis of the organisms should be a priority, before practical application as biopesticides could be considered. Later, Cameron (1969) reviewed the problems and prospects in the use of pathogens for insect control. He reported that *B. thuringiensis* and *B. papillae* were the most practical and most developed pathogens at the time. Other pathogens reported on in JESO include *Nosema* species (Microsporida), viruses, and pathogenic nematodes.

***Bacillus thuringiensis***. Angus and Heimpel (1960) reviewed the potential of bacteria for insect control. Among the several species mentioned, strains of *Bacillus thuringiensis* Berliner (*Bt*) were considered to be promising and the authors concluded that bacterial pathogens can be used to advantage in certain situations but they will never entirely replace chemical insecticides.

Angus (1965) studied the post-larval mortality of *Bt* on forest tent caterpillar, the Grey Midget, *Nycteola cinereana* Neumoegen and Dyar (Lepidoptera: Nolidae), and the Mourning Cloak, *Nymphalis antiopa* (L.) (Lepidoptera: Nymphalidae). Results showed that while most larvae were killed by *Bt* in the larval stage, some individuals of each species pupated; however, these did not survive and they contained *Bt* cells. Stewart et al. (1992) studied the factors affecting the efficacy of *Bt* serovar. *San Diego* against larvae of the Colorado potato beetle. They determined that young larvae are most susceptible and should be targeted when using this agent. Morris (1980) isolated microbial pathogens from the Maize Weevil, *Sitophilus zeamais* Motchulsky (Coleoptera: Curculionidae), including a *Bacillus* sp. from adults and two *Pseudomonas* spp. from larvae and pupae.

Tripp (1972) reported on field trials of *Bt* applications to control Eastern Spruce Budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae). Application rates of 3.6 and 4.0 billion International Units (BIU) / US gal / acre effected mortalities of 96–99% on balsam fir and 80–86% on white spruce 33 days after spraying, although the occurrence of frost shortly after spraying may have influenced mortality.

Cadogan et al. (1987) evaluated a formulation of *Bt* on Jack Pine Budworm, *Choristoneura pinus pinus* (Freeman) (Lepidoptera: Tortricidae). Futura®, a new *Bt* formulation effectively suppressed populations of *C. pinus pinus* and prevented serious defoliation of host tress when applied at a rate of 30 BIU/ha. Cadogan (1993) showed that

*C. pinus pinus* larvae that survived *Bt* applied at 30 BIU weighed significantly less than controls and *Bt* applied at 20 BIU, suggesting that weights of surviving larvae could be used as an additional criterion for assessing efficacy of *Bt*.

***Nosema* species** – Wilson (1978) determined that incidence of the microsporidian *Nosema fumiferanae* (Thompson) (Nosematidae) infections increased from 35.9–69.0% over a five-year period of outbreak of its host, eastern spruce budworm. Wilson (1981) looked at the effects of *N. fumiferanae* on rearing stock of this host. Synthetic diets allowed the host to cope better with infection by *N. fumiferana*. Wilson (1985a) studied transmission and effects of *N. fumiferanae* and *Pleistophora schubergi* Zwölfer (Pleistophoridae) on eastern spruce budworm. Males infected with either *N. fumiferanae* or *P. schubergi* did not transmit spores to uninfected females through mating. However, *P. schubergi* infection reduced pupal weight (about 30%) and adult longevity of females by 2.5 days. Wilson (1985b) studied dose mortality response of *P. schubergi* on eastern spruce budworm and found that a dose of $5 \times 10^5$ spores/larva caused >80% mortality of larvae and a dose of $5 \times 10^7$ spores/larva caused 100% mortality. Higher doses resulted in decreased survival times of infected larvae. Wilson (1987) found that *Vairimorpha necatrix* (Kramer) (Nosematidae) caused high mortality: a dose of $5 \times 10^4$ spores/needle caused 100% mortality. Large doses caused mortality by gut damage and bacterial septicemia, whereas low doses caused death by microsporidiosis usually just before pupation.

Wilson and Burke (1979) documented the presence of three microsporidians, *Nosema cerasivoranus* Thomson (Nosematidae), *Pleistophora* sp. (Pleistophoridae) and *Thelohania* sp. (Thelohaniidae) from larvae of the Ugly Nest Caterpillar, *Archips cerasivoranus* (Fitch) (Lepidoptera: Tortricidae). Levels of parasitism varied between years and among species, *Pleistophora* sp. at 3–35.9% was the most prevalent, followed by *N. cerasivoranae* at 0–28%, and *Thelohania* at 0–2.3%. Wilson (1980) examined the effects of *Nosema disstriae* Thompson (Nosematidae) on the forest tent caterpillar, *M. disstria*, finding that this microsporidian adversely affected pupal weights, adult fecundity and longevity.

Laing and Jaques (1985) studied Microsporidia associated with the European Corn Borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae) over a 7-year period. Applications of *Nosema pyrausta* (Paillot) (Nosematidae), *V. necatrix*, *Bt* and *Autographa californica* nuclear polyhedrosis virus (ACNPV) (*Baculoviridae*) had little or no effect on reducing crop damage compared to insecticides. However, Microsporidia infection levels of field collected corn borer larvae (17–40%) and adults (10–24%) did not result in reduced damage to the current crop but these authors concluded that infection levels may, over the longer term, reduce viability of populations of the pest.

**Viruses** – Cunningham et al. (1987) found the nuclear polyhedrosis virus *Lecontvirus* (*Baculoviridae*) to be highly effective against the Redheaded Pine Sawfly, *Neodiprion lecontei* (Fitch) (Hymenoptera: Tenthredinidae). A dose of $5 \times 10^9$ polyhedral inclusion bodies (PIB) per ha in spray volumes of 2.4–9.4 L/ha provided consistent control when applied to 1st–3rd instar larvae. The virus can be cheaply produced (50 infected larvae can produce enough concentrate for the $5 \times 10^9$ PIB/ha dose) at about $2.50/ha in 1985 dollars and applied using water alone. Evaluation of 100 trees, each with one redheaded pine sawfly colony and scoring colonies as healthy, diseased or dead, allowed reliable monitoring of epizootic progress. It was registered in Canada and was being used by Ontario.

Jaques (1971) studied the potential for use of viruses to control cabbage insect pests. Natural epizootics of the nuclear polyhedrosis viruses, *Tricoplusia ni NPV* (TnNPV) and *Pieris rapae GV* (PrGV) (*Baculoviridae*) contributed substantially to control of *T. ni* and *P. rapae* in the latter part of the season. Natural epizootics were the result of virus accumulations in the soil, TnNPV residues being found in 60% and *P. rapae* GV in 19% of samples taken. Application of the viruses to plants resulted in control as effective as or better than that provided by chemical pesticides.

Bird et al. (1973) studied the possible use of a *nuclear polyhedrosis virus* (NPV) and *entomopoxvirus* (EPV) (*Poxyviridae*) to control eastern spruce budworm. Both viruses were isolated from eastern spruce budworm and the Two-year-cycle Budworm, *Choristoneura biennis* Freeman (Lepidoptera: Tortricidae) from British Columbia. EPV was more effective on white spruce than on balsam fir in early season applications, while late spray of NPV was more effective. Virus carryover from 1971–1972 occurred.

Cunningham et al. (1996a) evaluated *Disparvirus*, nuclear polyhedrosis virus, and *Bt* serovar. *kurstaki* (*Btk*) applied as aerial sprays on mortality of gypsy moth. Average egg mass reductions from *Disparvirus* were 76% and 80% at a rates of 5.0 and 2.5 L/ha, respectively, and 96% for *Btk* at 50 billion International Units (BIU) in 4.0 L/ha. Cunningham et al. (1996b) reported on impact of *Disparvirus* and *Btk* one year after application. Gypsy moth, larvae were 20.4% positive for NPV in plots treated with *Disparvirus* at 5.0 L/ha, 14.6% positive for NPV in plots treated at 2.5 L/ha, and 8.0% positive for NPV in plots treated with *Btk*, and 9.2% positive for NPV in control plots. Negligible foliage damage was reported and fall egg mass numbers were low indicating that in the treated area, the gypsy moth population had collapsed, suggesting that NPV was a contributing factor.

**Nematodes** – Welch (1962) reviewed the status of nematodes as agents for insect control. In nature, nematodes are generally not significant mortality factors, although under some conditions they may be significant regulatory factors. Mermithidae have the greatest potential as biological control agents because of their size and similarity to insect parasitoids. Neoaplectanidae also show potential because of their high rate of reproduction. Allantonematidae and Aphelenchoidea are best suited to environmental manipulation. Moisture, moderate temperatures and high host density are important factors for successful control.

Welch and Briand (1962) evaluated a neoplectanid nematode for control of Colorado potato beetle, cabbage root maggot, European corn borer and the imported cabbage worm. Use of the nematode was most promising for control of cabbage root maggot and European corn borer where the soil environment provides conditions suitable for nematode survival.

Briand (1960) reported the occurrence of the nematode *Howardula beninga* Cobb (Tylenchida: Allantonematidae) in the Striped Cucumber Beetle, *Diabrotica vittata* (Fabricius) (Coleoptera: Chrysomelidae). Parasitism was 7.6% and 2.5% in surveys conducted in 1958 and 1959, respectively. Parasitism was nil in the secondary host *D. unidecimpunctata howardi* (Barber) even though this species was common in the southern Ontario study area.

Wright (1972) reported a new Canadian record for the adventive nematode *Heterotylenchus autumnalis* Nickle (Nematoda: Sphaerulariidae) as a parasite of the Face Fly, *Musca autumnalis* DeGeer (Diptera: Muscidae). *Heterotylenchus autumnalis* is widely distributed in Ontario but incidence was <2% and unlikely to contribute significantly to

natural control. Gregory and Wright (1973) released irradiated female face flies parasitized with *H. autumnalis* and found that doses of 1.0 and 2.5 krad did not sterilize the nematodes and parasitized face fly females produced progeny with high levels of parasitism. Release of sterile flies that were parasitized was considered better than the release of sterile flies alone.

Welch (1958) evaluated the nematode *Neaplectana chresima* Steiner (Rhabdidita: Steinernematidae) for biological control of Colorado potato beetle. Application of ~20,000 cultured nematodes resulted in an approximate 14% reduction in beetle numbers although abiotic factors, i.e., significant rainfall, had an impact on the nematodes.

**7. Natural Enemy Taxonomy**

Taxonomy is essential to biological control and a few studies on groups relevant to biological control have been published in JESO. These studies, while clarifying taxonomic status, unfortunately also demonstrate just how poorly the biology of parasitoids is understood. Six taxonomic studies published in JESO that are relevant to biological control treat taxa within the Hymenoptera familes Braconidae (2), Eucharitidae (1) and Mymaridae (3).

**Braconidae.** Loan (1970) described the new species, *Leiophron pseudopallipes* Loan and *Leiophron lygivora* (Loan) (Hymenoptera: Braconidae) reared from tarnished plant bug, *Lygus lineolaris*, in Ontario. *Leiophron pseudopallipes* is ecologically distinct, attacking 2nd generation *L. lineolaris*, from the related *L. mellipes* (Cresson) which attacks the 1st generation. *Leiophron lygivora* also attacks 2nd generation *L. lineolaris*. Loan and New (1972) reviewed the taxonomy of the Euphorine (Hymenoptera: Braconidae) genus *Leiophron*, subgenus *Euphoriella* Ashmead and redescribed *L.* (*E.*) *sommermanae* (Muesebeck), *L.* (*E.*) *incerta* (Ashmead), and *L.* (*E.*) *pacifica* (Muesebeck). *Leiophron* (*E.*) *nixoni* (Loan and New), *L.* (*E.*) *kaladarensis* (Loan and New), *L.* (*E.*) *solidaginis* (Loan and New), *L.* (*E.*) *foutsi* (Loan and New), *L.* (*E.*) *pallidifacia* (Loan and New), *L.* (*E.*) *hyalopsocidis* (Loan and New) and *L.* (*E.*) *criddlei* (Loan and New) were newly described. *Leiophron* (*E.*) *hyalopsocidis* was the only species associated with a host and it was reared from the psocid *Hyalopsocus striatus* (Walker) (Psocoptera: Psocidae).

Sharkey (2007) revised the Neotropical Braconidae (Hymenoptera) genus *Trachagathis* Viereck. Among the 3 species treated, *Trachagathis rubricincta* (Ashmead) is associated with the lesser cornstalk borer, *Elasmopalpus lingosellus* (Zeller) (Lepidoptera: Pyralidae), from sugarcane and the biologies of the other two species are unknown.

**Eucharitidae.** Heraty (1985) revised the Nearctic Eucharitinae (Hymenoptera: Eucharitidae), providing keys to the 5 genera and 16 species. Species of Eucharitidae are specialized ant parasitoids. Among the species treated, only the host of *Pseudometagea schwarzii* (Ashmead), the ant *Lasius neoniger* Emery (Hymenoptera: Formicidae), is known.

**Mymaridae.** Huber (1992) studied the subgenera and species groups of *Anaphes* (Hymenoptera: Mymaridae), and reviewed the described Nearctic species of the *fuscipennis* group of *Anaphes s.s.* and the described species of *Anaphes* (*Yungaburra*). *Anaphes* spp. are mostly parasitoids of Curculionidae and Chrysomelidae. Among the 9 species of the *Anaphes fuscipennis* group treated, hosts have been associated with *Anaphes fuscipennis* Haliday [*Sitona humeralis* Stephens, *Hypera postica* (Gyllenhal) and *H. punctata*

(Fabricius) (Coleoptera: Curculionidae)], *A. iole* Girault [*Lygus* spp. and *Pseudatomoscelis* sp. (Hemiptera: Miridae)], *A. byrrhidiphagus* Huber [*Lioon simplicipes* (Mannerheim) and *Lioligus nitidus* (Motschulsky) (Coleoptera: Byrridae)], and *Anaphes flavipes* (Förster) [*Oulema melanopus* (L.), *O. gallaeciana* (Heydon), *O. collaris* (Say), *Lema trilineata* Oliver, *L. trilineata trivittata* (Say), *L. lichenis* Voet. and *L. cyanella* (L.) (Coleoptera: Chrysomelidae)]. *Anaphes flavipes* was imported for biological control of *O. melanopus*. Hosts are unknown for the six species of the *Anaphes* (*Yungabura*) group.

Huber (2006) reviewed the described species of the *Anaphes crassicornis* group, important in biological control with the aim to improve identification of the species. Among the 13 species treated hosts are known for *Anaphes calendrae* (Gahan) [*Sphenophorus* spp. (Coleoptera: Curculionidae)], *A. conotracheli* Girault [*Conotrachelus geminatus* (LeConte), *Hypera nigrirostris* (Fabricius) (Coleoptera: Curculionidae)], *A. cotei* Huber [*Listronotus oregonensis* (LeConte) (Coleoptera: Curculionidae)], *A. diana* (Girault) [*Sitona hispidulus* (Fabricius), *S. humeralis* Stephens, *S. lineatus* (L.) (Coleoptera: Curculionidae)], *A. gerrisophagus* (Doutt) [*Gerris* sp. (Hemiptera: Gerridae) and *Lestes* sp. (Odonata: Lestidae)], *A. listronoti* Huber [*L. oregonensis*], *A. luna* (Girault) [*Hypera* spp., and in North America, *H. postica* (Gyllenhal) and *H. eximia* (LeConte) (Coleoptera: Curculionidae)], *A. pallipes* (Ashmead) [*Cylindrocopturus adspersus* (LeConte) (Coleoptera: Curculionidae) and *Rhagoletis pomonella* Walsh (Diptera: Tephritidae)], *A. pullicrurus* (Girault) [*Chaetoctema denticulata* (Illiger) (Coleoptera: Chrysomelidae)], *A. sordidatus* [*Tyloderma foveolatum* (Say) (Coleoptera: Curculionidae)], and *A. victus* Huber [*L. oregonensis*]. *Anaphes luna* and *A. diana* were imported and released in the USA as biological control agents.

Huber (2012) revised the *Ooctonus* spp. (Hymenoptera: Mymaridae) in the Nearctic region. Among the 15 species described, hosts are known for *O. aphrophorae* Milliron [on *Aphrophora saratogensis* (Fitch) (Hemiptera: Cercopidae)], and *O. vulgatus* Haliday [on *Philaenus spumarius* (L.) (Hemiptera: Cercopidae)]. Although white pine weevil was recorded as a potential host for *O. quadricarinatus* Girault the record is incorrect (J. Huber, personal communication).

## Conclusions

Over the years, the *Journal of the Entomological Society of Ontario* has been an important venue for dissemination of scientific results on biological control of pest arthropods and weeds in Ontario. Included are studies on natural enemy assemblages, biology of natural enemies, releases of exotic species as agents for biological control, entomopathogens for use in reduced risk management strategies, and taxonomy of groups important to biological control. In recent years, competition with an ever increasing number of specialized journals with high impact factors, many of which have no page charges, has led to a decline in submissions to JESO. However, there are unfilled niches for which JESO can provide a good opportunity to publish: documenting the status and distribution of natural enemies intentionally released as biological control agents, documenting associations among natural enemies and hosts, and assessing changes in natural enemy assemblages over time.

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TABLE 1. Natural enemies introduced as classical biological control agents of invasive alien weeds in Ontario, 1952–2012.

| Scientific name | Common name | Year first reported | Biological control agent | Year introduced | Reference |
|---|---|---|---|---|---|
| *Carduus nutans* L. (*Asteraceae*) | Nodding Thistle | 1920[1] | *Rhinocyllus conicus* Froelich (Coleoptera: Cuculionidae) | 1968 | Laing & Heels (1979) |
| *Cirsium arvense* (L.) Scopoli (*Asteraceae*) | Canada Thistle | 17th century[2] | *Urophora cardui* L. (Diptera: Tephritidae) | 1975 | Laing (1978) |
| *Euphorbia esula* L. (*Euphorbiaceae*) | Leafy Spurge | 1889[3] | *Aphthona nigriscutis* Foudras (Coleoptera: Curculionidae) | 1988 | LeSage (1989) |
| | | | *Aphthona flava* Guillebeau (Coleoptera: Curculionidae) | 1988 | LeSage (1989) |
| *Hypericum perforatum* L. (*Hyperiaceae*) | St. John's Wort | 1800s[4] | *Chrysolina hyperici* (Förster) (Coleoptera: Chrysomelidae) | 1969 | LeSage (1996b) |
| *Lythrum salicaria* L. (*Lythraceae*) | Purple Loosestrife | Early 19th century | *Neogalerucella calmariensis* (L.) [=*Galerucella calmariensis* L.] (Coleoptera: Curculionidae) | 1992 | Corrigan et al. (1998) |

[1]Mulligan and Frankton (1954), [2]Moore (1975), [3]Best et al. (1980), [4]Crompton et al. (1988).

TABLE 2. Natural enemies introduced as classical biological control agents of invasive alien arthropods in Ontario, 1952–2012.

| Scientific name | Common name | Year first reported | Biological control agent | Year introduced | Reference |
|---|---|---|---|---|---|
| *Acyrtosiphon pisum* (Harris) (Hemiptera: Aphididae) | Pea Aphid | 1890s[1] | *Aphidius smithi* Sharma and Subba Rao (Hymenoptera: Aphidiidae) | 1950s in USA | Mackauer & Bisdee (1965) |
| *Agromyza frontella* (Rondell) (Diptera: Agromyzidae) | Alfalfa Leaf Blotch Miner | Mid-1970s | *Dacnusa dryas* (Nixon) (Hymenoptera: Braconidae) | 1979 | Harcourt et al. (1987) |
| | | | *Diglyphus isaea* (Walker) (Hymenoptera: Eulophidae) | 1975 (northeastern USA) | Coote & Ellis (1987) |
| | | | *Cyrtogaster vulgaris* Walker (Hymenoptera: Pteromalidae) | 1976 (northeastern USA) | Coote & Ellis (1987) |
| *Coleophora deauratella* Lienig & Zeller (Lepidoptera: Coleophoridae) | Red Clover Case-bearer | 1989 | *Neochrysocharis formosa* (Westwood) (Hymenoptera: Eulophidae) | 1993[2], 1995[2] | Ellis and Bjornson (1996) |
| *Coleophora laricella* (Hübner) (Lepidoptera: Coleophoridae) | Larch Casebearer | 1935–1941 | *Chrysocharis laricinellae* (Ratzeburg) (Hymenoptera: Eulophidae) | 1935–1941 | Graham (1958) |
| | | | *Agathis pumilus* (Ratzeburg) (Hymenoptera : Braconidae) | 1935–1941 | Graham (1958) |
| *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) | Codling Moth | 1958–1960 | *Liotryphon caudatus* (Ratzeburg) [=*Apistephialtes caudata* (Ratzeburg)] (Hymenoptera: Ichneumonidae) | 1941–1945 | Putnam (1963) |
| | | | *Nippocryptus vittatorius* (Jurine) [=*Cryptus sexannulatus* Gravenhorst] (Hymenoptera: Ichneumonidae) | 1941–1945 | Putnam (1963) |
| | | | *Elodia tragica* (Meigen) (Diptera: Tachinidae) | 1943–1944 | Putnam (1963) |
| | | | *Pristomerus vulnerator* Panzer (Hymenoptera: Ichneumonidae) | 1943–1944 | Putnam (1963) |
| *Hydraecia micacea* (Esper) (Lepidoptera: Noctuidae) | Potato Stem Borer | 1968 | *Lydella stabulans* Fallén (Diptera : Tachnidae) | 1983 | West et al. (1984) |

TABLE 2 continued...

| Scientific name | Common name | Year first reported | Biological control agent | Year introduced | Reference |
|---|---|---|---|---|---|
| *Hydraecia micacea* (Esper) (Lepidoptera: Noctuidae) | Potato Stem Borer | | *Macrocentrus blandus* Eady and Clark (Hymenoptera: Braconidae) | 1983 | West et al. (1984) |
| *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) | Alfalfa Weevil | 1960 | *Bathyplectes anurus* (Thomson) (Hymenoptera: Ichneumonidae) | 1970 | Harcourt & Ellis (1992) |
| | | | *Perilitus aethiops* Nees [=*Microctonus aethiopoides* Loan] (Hymenoptera: Braconidae) | 1970–1971 | Harcourt et al. (1980) |
| | | | *Perilitus colsei* (Drea) [=*Microctonus colesi* Drea] (Hymenoptera: Braconidae) | 1970 | Harcourt et al. (1982) |
| | | | *Zoophthora phytonomi* (Arthur) Batko (Entomophthoraceae) | | Harcourt & Ellis (1992) |
| *Lymantria dispar* (L.) (Lepidoptera: Erebidae) | Gypsy Moth | 1969 | *Cotesia melanoscela* (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)] (Hymenoptera: Braconidae) | Not introduced into Ontario | Griffiths (1977) |
| | | | *Compsilura concinnata* (Meigen) (Diptera: Tachinidae) | 1916 | Griffiths (1977) |
| | | | *Parasetigena agilis* (Robineau-Desvoidy) (Diptera: Tachinidae) | Not introduced into Ontario | Griffiths (1977) |
| | | | *Ceranthia samarensis* (Villeneuve) (Diptera: Tachinidae) | 1991–1996 | Nealis and Quednau (1996) |
| *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae) | Cereal Leaf Beetle | 1965 | *Tetrastichus julis* (Walker) (Hymenoptera : Eulophidae) | 1974 | Ellis et al. (1979) |
| *Pieris rapae* (L.) (Lepidoptera: Pieridae) | Imported Cabbageworm | 1871 | *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) | 1991–1992 | Carter & Laing (1997) |
| *Psila rosae* (Fabricius) (Diptera: Psilidae) | Carrot Rust Fly | 1885 | *Dacnusa gracilis* (Nees) (Hymenoptera: Braconidae) | 1949–1953 | Maybee (1954) |
| | | | *Loxotropa tritoma* (Thomson) (Hymenoptera: Proctotrupidae) | 1949–1953 | Maybee (1954) |

TABLE 2 continued...

| Scientific name | Common name | Year first reported | Biological control agent | Year introduced | Reference |
|---|---|---|---|---|---|
| *Rhyacionia buoliana* (Schiffermüller) (Lepidoptera: Tortricidae) | European Pine Shoot Moth | 1925 | *Campoplex difformis* (Gmelin) [=*Campoplex mutabilis* (Holmgren)] (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Sinophorus turionum* (Ratzeburg) [=*Campoplex rufifemur* (Thomson)] (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Copidosoma filicorne* (Dalman) [=*Copidosoma geniculatum* (Dalman)] (Hymenoptera: Eulophidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Temeluca interruptor* (Gravenhorst) [=*Cremastus interruptor* (Gravenhorst)] (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Exeristes ruficollis* (Gravenhorst) [=*Ephialtes ruficollis* (Gravenhorst)] (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Orgilus obscurator* (Nees) (Hymenoptera: Braconidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Pimpla turionellae* (L.) (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Pimpla* sp. (Hymenoptera: Ichneumonidae) | 1928–1953 | Coppel & Arthur (1954) |
| | | | *Baryscapus turionum* (Hertig) [=*Tetrastichus turionum* (Hertig)] (Hymenoptera: Eulophidae) | 1928–1953 | Coppel & Arthur (1954) |

[1] Mackauer, M. 1971. 2. *Acyrthosiphon pisum* (Harris), pea aphid (Homoptera: Aphididae). In: *Biological control programmes against insects and weeds in Canada 1959-1968*. Technical Communication Commonwealth Institute of Biological Control 4: 3–10.

[2]Some uncertainty whether populations released were *N. formosa* or *N. trifolii* (see text).

TABLE 3. Pathogens evaluated as inundative biological control agents of pest insects in Ontario, 1952–2012.

| Scientific name | Common name | Biological control agent | Reference |
|---|---|---|---|
| *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae) | Spruce Budworm | *Bacillus thuringiensis* Berliner (Bacilliaceae) | Tripp (1972) |
| | | *Entomopox virus* (EPV) (*Baculoviridae*) | Bird et al. (1973) |
| | | *Nosema fumiferanae* (Thompson) (Nosematidae) | Wilson (1978; 1981; 1985a) |
| | | *nuclear polyhedrosis virus* (NPV) (*Baculoviridae*) | Bird et al. (1973) |
| | | *Pleistophora schubergi* Zwölfer (Pleistophoridae) | Wilson (1985a, b) |
| | | *Vairimorpha necatrix* (Kramer) (Nosematidae) | Wilson (1987) |
| *Choristoneura pinus pinus* (Freeman) (Lepidoptera: Tortricidae) | Jack Pine Budworm | *Bacillus thuringiensis* Berliner (Bacilliaceae) | Cadogan et al. (1987); Cadogan (1993) |
| *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) | Colorado Potato Beetle | *Bacillus thuringiensis* Berliner serovar. *San Diego* (Bacilliaceae) | Stewart et al. (1992) |
| | | *Neaplectana chresima* Steiner (Nematoda: Steinernematidae) | Welch (1958) |
| *Lymantria dispar* (L.) (Lepidoptera: Erebidae) | Gypsy Moth | *Bacillus thuringiensis* Berliner serovar. *kurstaki* (Bacilliaceae) | Cunningham et al. (1996a, b) |
| | | *nuclear polyhedrosis virus* (NPV) (*Baculoviridae*) | Cunningham et al. (1996a, b) |
| *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae) | Forest Tent Caterpillar | *Bacillus thuringiensis* Berliner (Bacilliaceae) | Angus (1965) |
| *Neodiprion lecontei* (Fitch) (Hymenoptera: Tenthredinidae) | Redheaded Pine Sawfly | *Lecontvirus* (*Baculoviridae*) | Cunningham et al. (1987) |
| *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae) | European corn borer | *Autographa californica nuclear polyhedrosis virus* (ACNPV) (*Baculoviridae*) | Laing & Jaques (1985) |
| | | *Bacillus thuringiensis* Berliner (Bacilliaceae) | Laing & Jaques (1985) |
| | | *Nosema pyrausta* (Paillot) (Nosematidae) | Laing & Jaques (1985) |
| | | *Vairimorpha necatrix* (Kramer) (Nosematidae) | Laing & Jaques (1985) |
| *Pieris rapae* (L.) (Lepidoptera: Pieridae) | Imported cabbageworm | *Pieris rapae GV* (*Baculoviridae*) | Jaques (1971) |
| *Tricoplusia ni* (Hübner) (Lepidoptera: Noctuidae) | Cabbage looper | *Tricoplusia ni GV* (*Baculoviridae*) | Jaques (1971) |

APPENDIX A. Natural Enemies of insects and weeds reported in JESO (1952–2012). Correct name is first, followed by names as spelled in JESO in brackets, if they are different.

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Actebia fennica* (Tauscher) (Lepidoptera: Noctuidae) | *Arenetra rufipes* Cresson | Hymenoptera | Ichneumonidae | parasitoid | West (1992) |
| | *Campoletis* sp. | Hymenoptera | Ichneumonidae | parasitoid | West (1992) |
| | *Enicospilus* sp. | Hymenoptera | Ichneumonidae | parasitoid | West (1992) |
| | *Gonia* sp. | Diptera | Tachinidae | parasitoid | West (1992) |
| | *Ichneumon creperus* Cresson | Hymenoptera | Ichneumonidae | parasitoid | West (1992) |
| | *Steinernema feltiae* (Filipjev) | Rhabiditida | Steinernematidae | parasite | West (1992) |
| | *Tachinomyia panaetius* (Walker) | Diptera | Tachinidae | parasitoid | West (1992) |
| *Acrobasis* sp. (Lepidoptera: Pyralidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Acrobasis vaccinii* Riley [=*Mineola vaccinii* (Riley)] (Lepidoptera: Pyralidae) | *Phanerotoma franklini* Gahan | Hymenoptera | Braconidae | parasitoid | Maxwell & Morgan (1952) |
| | *Cryptus albitarsis* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Maxwell & Morgan (1952) |
| *Aculus schlechtendali* (Nalepa) (Trombidiformes: Eriophyidae) | *Balaustium putnami* Smiley | Trombidiformes | Erythraeidae | predator | Cadogan & Laing (1982) |
| | *Dendroptus* n. sp. near *suskii* Sharonov and Livshitz [=*Dendroptus forestae* Lindquist)] | Trombidiformes | Tarsonemidae | predator | Villanueva & Harmsen (1996) |
| | *Phytocoris* sp. | Hemiptera | Miridae | predator | Hagley (1979) |
| | *Zetzellia mali* (Ewing) | Trombidiformes | Stigmaeidae | predator | Clements (1989) |
| *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae) | *Aphelinus howardii* (Ashmead) [=*Aphelinus howardii* Dalla Torre] | Hymenoptera | Aphelinidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Aphelinus semiflavus* Howard | Hymenoptera | Aphelinidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Aphidius colemani* Viereck [=*Aphidius platensis* Brèthes] | Hymenoptera | Aphidiidae | parasitoid | Vander Hoek (1971) |
| | *Aphidius ervi* Haliday | Hymenoptera | Aphidiidae | parasitoid | Vander Hoek (1971) |
| | *Aphidius nigripes* Ashmead [=*Aphidius pulcher* Baker] | Hymenoptera | Aphidiidae | parasitoid | Mackauer & Bisdee (1965); Vander Hoek (1971) |
| | *Aphidius smithi* Sharma & Subba Rao | Hymenoptera | Aphidiidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Diaeretiella rapae* (McIntosh) [=*Diaeretus rapae* (Curtis)] | Hymenoptera | Braconidae | parasitoid | Vander Hoek (1971) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Ephedrus californicus* Baker | Hymenoptera | Aphidiidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Erynia neoaphidis* Remaudière & Hennebert | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Monoctonus crepidis* (Haliday) [=*Monoctonus paludum* Marshall] | Hymenoptera | Braconidae | parasitoid | Vander Hoek (1971) |
| | *Monoctonus nervosus* (Haliday) [=*Monoctonus paulensis* (Ashmead)] | Hymenoptera | Braconidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Praon pequodorum* Viereck | Hymenoptera | Aphidiidae | parasitoid | Mackauer & Bisdee (1965) |
| | *Praon* sp. | Hymenoptera | Aphidiidae | parasitoid | Mackauer & Bisdee (1965) |
| *Adelphocoris lineolatus* (Goeze) (Hemiptera: Miridae) | *Leiophron dayi* (Goulet) [=*Peristenus dayi* Goulet | Hymenoptera | Braconidae | parasitoid | Mason et al. (2011) |
| | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| | *Leiophron rubricollis* (Thomson) [=*Peristenus rubricollis* (Thomson)] | Hymenoptera | Braconidae | parasitoid | Mason et al. (2011) |
| *Adelphocoris rapidus* Say (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Aedes aegypti* (L.) (Diptera: Culicidae) | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| *Agromyza frontella* (Rondani) (Diptera: Agromyzidae) | *Asaphes vulgaris* Walker | Hymenoptera | Pteromalidae | parasitoid | Coote & Ellis (1987a) |
| | *Baryscapus racemariae* (Ashmead) [=*Tetrastichus centricolae* (Ashmead)] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Chrysocharis giraulti* Yoshimoto | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Chrysocharis liriomyzae* Delucchi [=*Chrysocharis punctifacies* Delucchi] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Closterocerus cinctipennis* Ashmead | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Closterocerus trifasciatus* Westwood [=*Closterocerus tricinctus* (Ashmead)] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Cyrtogaster vulgaris* Walker | Hymenoptera | Pteromalidae | parasitoid | Coote & Ellis (1987a) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Dacnusa dryas* (Nixon) | Hymenoptera | Braconidae | parasitoid | Coote & Ellis (1987a); Harcourt et al. (1987) |
| | *Diaulinopsis albiscapus* (Girault) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Diaulinopsis callichroma* Crawford | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Diglyphus begini* (Ashmead) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Diglyphus intermedius* (Girault) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Diglyphus isaea* (Walker) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Diglyphus pulchripes* (Crawford) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Eunotus* sp. | Hymenoptera | Pteromalidae | parasitoid | Coote & Ellis (1987a) |
| | *Hemiptarsenus ainsliei* (Crawford) [=*Notanisomorpha ainsliei* Crawford] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Miscogaster hortensis* Walker | Hymenoptera | Pteromalidae | parasitoid | Coote & Ellis (1987a) |
| | *Necremnus* sp. | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Pnigalio maculipes* (Crawford) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Pnigalio uroplatae* (Howard) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Sympiesis ancylae* Girault | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Sympiesis enargiae* Miller | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Sympiesis sericeicornis* (Nees) [=*Sympiesis conica* (Provancher)] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Sympiesis* sp. | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Sympiesis viridula* (Thomson) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Tetrastichus* n. sp. | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| | *Tetrastichus cincinnatus* (Girault) [=*Aprostocetus cincinnatus* (Girault)] | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987a) |
| *Ancylis comptana* (Frölich) [=*Ancylis comptana fragariae* (Walsh & Riley)] (Lepidoptera: Tortricidae) | *Macrocentrus ancylivora* Rohwer | Hymenoptera | Braconidae | parasitoid | Dustan & Boyce (1966) |
| *Anisoplia austriaca* (Herbst) (Coleoptera: Scarabaeidae) | *Metarrhizium anisopliae* (Metchnikoff) Sorokin | | Clavicipitaceae | pathogen | Cameron (1969) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| aphids (Hemiptera: Aphididae) | *Adialytus salicaphis* (Fitch) [=*Diaeretus salicaphis* (Fitch)] | Hymenoptera | Braconidae | parasitoid | Judd (1953) |
| | *Aphidius matricariae* Haliday [=*Aphidius phorodontis* Ashmead] | Hymenoptera | Aphidiidae | parasitoid | Judd (1953) |
| | *Asaphes suspensus* (Nees) [=*Asaphes rufipes* Brues] | Hymenoptera | Pteromalidae | parasitoid | Judd (1953) |
| *Aphidius phorodontis* Ashmead (Hymenoptera: Braconidae) | *Lygocerus* sp. | Hymenoptera | Ceraphronidae | hyperparasitoid | Judd (1953) |
| | *Alloxysta* sp. [=*Charipes* sp.] | Hymenoptera | Aloxystidae | hyperparasitoid | Judd (1953) |
| *Aphis glycines* Matsumura (Hemiptera: Aphididae) | *Harmonia axyridis* (Pallas) | Coleoptera | Coccinellidae | predator | Bahlai et al. (2009) |
| *Aphis pomi* DeGeer (Hemiptera: Aphididae) | *Deraeocoris fasciolus* Knight | Hemiptera | Miridae | predator | Hagley (1979) |
| *Aprophora saratogensis* (Fitch) (Hemiptera: Cicadellidae) | *Ooctonus aphrophorae* Milliron | Hymenoptera | Mymaridae | parasitoid | Huber (2012) |
| *Schizocerella pilicornis* (Holmgren) [=*Aprosthena zabriskei* Webster & Malley] (Hymenoptera: Argidae) | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Archips cerasivorana* (Fitch) (Lepidoptera: Tortricidae) | *Nosema scerasivoranus* Thomson | | Nosematidae | pathogen | Wilson & Burke (1979) |
| | *Pleistophora* sp. | | Pleistophoridae | pathogen | Wilson & Burke (1979) |
| | *Thelohania* sp. | | Thelohaniidae | pathogen | Wilson & Burke (1979) |
| *Archips purpuranus* Clemens (Lepidoptera: Tortricidae) | *Macrocentrus nigridorsis* Viereck | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| | *Microgaster canadensis* Muesebeck [=*Microgaster canadensis* Muesbeck] | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| | *Oncophanes americanus* (Weed) [=*Oncophanes atriceps* (Ashmead) =*Oncophanes canadensis* (Muesbeck)] | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| *Archips rosana* (L.) (Lepidoptera: Tortricidae) | *Euema caesar* (Aldrich) [=*Zenilla caesar* Aldrich] | Diptera | Tachinidae | parasitoid | Hagley & Barber (1992) |
| | *Microgaster canadensis* Muesebeck | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| | *Phorocera erecta* Coquillett | Diptera | Tachinidae | parasitoid | Hagley & Barber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Archips* spp. (Lepidoptera: Tortricidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Argyrotaenia velutinana* (Walker) (Lepidoptera: Tortricidae) | *Phytodietus vulgaris* Cresson [=*Phytodietus annulatus* (Provancher)] | Hymenoptera | Ichneumonidae | parasitoid | Hikichi (1962); Hagley & Barber (1992) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hikichi (1962); Hagley & Barber (1992) |
| *Ascogaster quadridentata* Wesmael (Hymenoptera: Braconidae) | *Dibrachys microgastri* (Bouché) [=*Dibrachys cavus* (Walker)] | Hymenoptera | Pteromalidae | hyperparasitoid | Putnam (1963) |
| | *Perilampus fulvicornis* Ashmead | Hymenoptera | Perilampidae | hyperparasitoid | Putnam (1963) |
| | *Perilampus* sp. | Hymenoptera | Perilampidae | hyperparasitoid | Putnam (1963) |
| | *Perilampus tristis* Mayr | Hymenoptera | Perilampidae | hyperparasitoid | Putnam (1963) |
| *Autographa californica* (Speyer) (Lepidoptera: Noctuidae) | *Cotesia yakutatensis* (Ashmead) [=*Apanteles yakutatensis* (Ashmead)] | Hymenoptera | Braconidae | parasitoid | West et al. (1984) |
| *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae) | *Agrothereutes abbreviatus iridescens* (Cresson) [=*Agrothereutes abbreviator similaris* (Provancher)] | Hymenoptera | Ichneumonidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Agrothereutes* sp. | Hymenoptera | Ichneumonidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Conura albifrons* (Walsh) [=*Spilochalcis albifrons* (Walsh)] | Hymenoptera | Chalcididae | hyperparasitoid | Abu & Ellis (1976) |
| | *Eupelmella vesicularis* (Retzius) | Hymenoptera | Eupelmidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Eupelmus* sp. | Hymenoptera | Eupelmidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Gelis* sp. | Hymenoptera | Ichneumonidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Habrocytus* sp. | Hymenoptera | Pteromalidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Pteromalus* sp. | Hymenoptera | Pteromalidae | hyperparasitoid | Abu & Ellis (1976) |
| | *Trichomalopsis viridescens* (Walsh) [=*Eupteromalus viridescens* (Walsh)] | Hymenoptera | Pteromalidae | hyperparasitoid | Abu & Ellis (1976) |
| *Bombus fervidus* (Fabricius) (Hymenoptera: Apidae) | *Brachicoma devia* Fallen | Diptera | Sarcophagidae | parasitoid | MacFarlane & Pengelly (1978) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | Edwards & Pengelly (1966); MacFarlane & Pengelly (1978) |
| *Bombus impatiens* Cresson (Hymenoptera: Apidae) | *Brachicoma setosa* Coquillett | Diptera | Sarcophagidae | parasitoid | MacFarlane & Pengelly (1978) |
| | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | MacFarlane & Pengelly (1978) |
| *Bombus laboriosus* (Fabricius) [=*Psithyrus laboriosus* (Fabricius)] (Hymenoptera: Apidae) | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | Edwards & Pengelly (1966) |
| *Bombus perplexus* Cresson (Hymenoptera: Apidae) | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | MacFarlane & Pengelly (1978) |
| *Bombus vagans* Smith (Hymenoptera: Apidae) | *Brachicoma sarcophagina* (Townsend) | Diptera | Sarcophagidae | parasitoid | MacFarlane & Pengelly (1978) |
| | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | MacFarlane & Pengelly (1978) |
| *Bombyx mori* (L.) (Lepidoptera: Bombycidae) | *Bacillus thuringiensis* Berliner serovar. *sotto* Aoki & Chigasaki | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| *Bruchophagus platyptera* (Walker) [=*Bruchophagus platypterus* (Walker)] (Hymenoptera: Eurytomidae) | *Tetrastichus bruchophagi* Gahan | Hymenoptera | Pteromalidae | parasitoid | Ellis & Nang'ayo (1992) |
| | *Mesopolobus bruchophagi* (Gahan) | Hymenoptera | Pteromalidae | parasitoid | Ellis & Nang'ayo (1992) |
| *Cacopsylla pyricola* (Förster) [=*Psylla pyricola* Förster] (Hemiptera: Psyllidae) | *Adalia bipunctata* (L.) | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Adalia bipunctata frigida* Schneider [=*Adalia frigida* Schneider] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Agulla* sp. | Neuroptera | Rhaphidiidae | predator | Philogene & Chang (1979) |
| | *Anthocoris antevolens* White | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Anthocoris melanocerus* Reuter | Hemiptera | Anthocoridae | predator | Wilde (1965); Philogene & Chang (1979) |
| | *Anthocoris musculus* Say | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Anthocoris nemoralis* (Fabricius) | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Anthocoris nemorum* L. | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Anthocoris pilosus* (Jakovlev) | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Anthocoris* sp. | Hemiptera | Anthocoridae | predator | Wilde (1965) |
| | *Anthocoris whitei* Reuter | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Asaphes vulgaris* Walker | Hymenoptera | Pteromalidae | parasitoid/ hyperparasitoid | Philogene & Chang (1979 |
| | *Atractotomus mali* Meyer | Neuroptera | Chrysopidae | predator | Philogene & Chang (1984 |
| | *Calvia quatuordecimguttata* (L.) [=*Anisoclavia quatuordecimguttata* L. =*Calvia duodecimmaculata* Gebler] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Campylomma verbasci* (Meyer-Dür) | Hemiptera | Miridae | predator | Philogene & Chang (1979) |
| | *Ceratomegilla* sp. | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979); Wilde (1965) |
| | *Chrysopa carnea* Stephens | Neuroptera | Chrysopidae | predator | Philogene & Chang (1985) |
| | *Chrysopa oculata* Say | Neuroptera | Chrysopidae | predator | Philogene & Chang (1986) |
| | *Chrysopa ploribunda* Fitch | Neuroptera | Chrysopidae | predator | Philogene & Chang (1987) |
| | *Chrysopa* sp. | Neuroptera | Chrysopidae | predator | Wilde (1965); Philogene & Chang (1979) |
| | *Coccidencyrtus* sp. | Hymenoptera | Pteromalidae | parasitoid | Philogene & Chang (1980; 1981) |
| | *Coccinella transversoguttata richarsoni* Brown [=*Coccinella transversoguttata* Falderman] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Coleomegilla maculata fuscilabris* (Mulsant) [=*Magilla fuscilabris* Mulsant] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Cycloneda polita* Casey | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Cycloneda* sp. | Coleoptera | Coccinellidae | predator | Wilde (1965) |
| | *Dendrocerus floridanus* (Ashmead) [=*Lygocerus semiramosuns* Kieffer] | Hymenoptera | Ceraphronidae | parasitoid | Philogene & Chang (1979) |
| | *Deraeocoris brevispiceatus* Knight [=*Derseocoris brevispiceatus* Knight] | Hemiptera | Miridae | predator | Philogene & Chang (1979) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Deraeocoris fasciolus* Knight [=*Derseocoris fasciolus* Knight] | Hemiptera | Miridae | predator | Philogene & Chang (1979) |
| | *Diaphnocoris provancheri* (Burque) | Hemiptera | Miridae | predator | Philogene & Chang (1979) |
| | *Encyrtus* sp. | Hymenoptera | Encyrtidae | parasitoid | Philogene & Chang (1979) |
| | *Endopsylla agilis* de Meijere | Diptera | Cecidomyiidae | parasitoid | Philogene & Chang (1979) |
| | *Endopsylla* sp. | Diptera | Cecidomyiidae | parasitoid | Philogene & Chang (1979) |
| | *Hemerobius pacificus* Banks | Neuroptera | Hemerobiidae | predator | Philogene & Chang (1979) |
| | *Hemerobius angustus* Banks | Neuroptera | Hemerobiidae | predator | Philogene & Chang (1979) |
| | *Hemerobius* sp. | Neuroptera | Hemerobiidae | predator | Philogene & Chang (1979) |
| | *Hippodamia convergens* Guérin-Méneville [=*Hyppodamia convergens* Guérin-Méneville] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Hippodamia quinquesignata* (Kirby) [=*Hyppodamia quinquesignata* (Kirby)] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Hippodamia* sp. | Coleoptera | Coccinellidae | predator | Wilde (1965) |
| | *Hippodamia tredecimpunctata tibialis* (Say) [=*Hyppodamia tredecimpunctata tibialis* (Say)] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Lasius pallitarsi* (Provancher) [=*Lasius sitkaenisis* Pergande] | Hymenoptera | Formicidae | predator | Philogene & Chang (1979) |
| | *Lygocerus* sp. | Hymenoptera | Ceraphronidae | parasitoid | Philogene & Chang (1979) |
| | *Olla v-nigrum* (Mulsant) [=*Olla abdominalis* Say] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Orius* sp. | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Orius tristicolor* (White) | Hemiptera | Anthocoridae | predator | Philogene & Chang (1979) |
| | *Pachyneuron californicum* Girault | Hymenoptera | Pteromalidae | parasitoid/ hyperparasitoid | Philogene & Chang (1982) |
| | *Pachyneuron* sp. | Hymenoptera | Pteromalidae | parasitoid | Philogene & Chang (1983) |
| | *Platypalpus* sp. | Diptera | Hybotidae | predator | Philogene & Chang (1979) |
| | *Prionomitus mitratus* (Dalman) | Hymenoptera | Encyrtidae | parasitoid | Philogene & Chang (1979) |
| | *Psyllaephagus* sp. | Hymenoptera | Encyrtidae | parasitoid | Philogene & Chang (1979) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Scymnus marginicollis* Mannerham [=*Scymnus marginiccelis* Mannerham] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Spaherosphoria* sp. | Diptera | Syrphidae | predator | Philogene & Chang (1979) |
| | *Stethorus punctum picipes* Casey [=*Stethocrus picipes* Casey] | Coleoptera | Coccinellidae | predator | Philogene & Chang (1979) |
| | *Trechnites insidiosus* (Crawford) [=*Trechnites psyllae* (Ruschka)] | Hymenoptera | Encyrtidae | parasitoid | Wilde (1965); Philogene & Chang (1979) |
| *Carduus acanthoides* L. (*Asteraceae*) | *Rhinocyllus conicus* Frölich | Coleoptera | Curculionidae | phytophage | Laing & Heels (1979) |
| *Carduus nutans* L. (*Asteraceae*) | *Papaipema nebris* Guenée [=*Papaipema negris* Guenée] | Lepidoptera | Noctuidae | phytophage | Laing & Heels (1979) |
| | *Platyptilia carduidactyla* (Riley) | Lepidoptera | Pterophoridae | phytophage | Laing & Heels (1979) |
| | *Rhinocyllus conicus* Frölich | Coleoptera | Curculionidae | phytophage | Laing & Heels (1979) |
| *Chaetocnema denticulata* (Illiger) (Coleoptera: Chrysomelidae) | *Anaphes pullicrurus* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Chlamydatus* sp. (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Chlorochroa sayi* Stål (Hemiptera: Pentatomidae) | *Telenomus utahensis* Ashmead | Hymenoptera | Scelionidae | parasitoid | Wang & Laing (1989) |
| *Chlorochroa uhleri* Stål (Hemiptera: Pentatomidae) | *Telenomus utahensis* Ashmead | Hymenoptera | Scelionidae | parasitoid | Wang & Laing (1989) |
| *Choristoneura biennis* Freeman (Lepidoptera: Tortricidae) | *entomopoxvirus EPV* | | *Poxyviridae* | pathogen | Bird et al. (1973) |
| *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Tripp (1973) |
| | *entomopoxvirus EPV* | | *Poxyviridae* | pathogen | Bird et al. (1973) |
| | *Nosema fumiferanae* (Thomson) | | Nosematidae | pathogen | Wilson (1978; 1985a; 1987) |
| | *Nosema fumiferanae* (Thomson) | | Nosematidae | pathogen | Wilson (1981) |
| | *Pleistophora schubergi* Zwölfer | | Pleistophoridae | pathogen | Wilson & Burke (1979); Wilson (1985a; b) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Pleistophora* sp. | | Pleistophoridae | pathogen | Wilson & Burke (1979) |
| | *polyhedrosis virus NPV* | | *Baculoviridae* | pathogen | Bird et al. (1973) |
| | *Thelohania* sp. | | Nosematidae | pathogen | Wilson (1987) |
| | *Thelohania* sp. | | Thelohaniidae | pathogen | Wilson & Burke (1979) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Corrigan et al. (1994) |
| | *Vairimorpha necatrix* (Kramer) | Dissociodihaplo-phasida | Nosematidae | pathogen | Wilson (1987) |
| *Choristoneura pinus pinus* (Freeman) (Lepidoptera: Tortricidae) | *Bacillus thuringiensis* Berliner serovar. *kurstaki* | | Bacillaceae | pathogen | Cadogan et al. (1987); Cadogan (1993) |
| *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae) | *Acropimpla alboricta* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Actia interrupta* Curran | Diptera | Tachinidae | parasitoid | Hagley & Barber (1992) |
| | *Agrypon* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Apophua simplicipes* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Colpoclypeus florus* (Walker) | Hymenoptera | Eulophidae | parasitoid | Hagley & Barber (1992) |
| | *Elachertus* sp. | Hymenoptera | Eulophidae | parasitoid | Hagley & Barber (1992) |
| | *Glypta fumiferanae* (Viereck) | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Glypta* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Macrocentrus linearis* (Nees) [=*Macrocentrus irridescens* (French)] | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| | *Nilea erecta* (Coquillet) | Diptera | Tachinidae | parasitoid | Hagley & Barber (1992) |
| | *Phytodietus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Phytodietus vulgaris* Cresson | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Pimpla aequalis* Provancher | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Scambus versicarius* Ratzeburg | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Barber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Chrysops frigidus* Osten-Sacken [=*Chrysops frigida* Osten-Sacken] (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| *Chrysops furcatus* Walker [=*Chrysops furcata* Walker] (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| *Chrysops* spp. (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| | *Prionocera dmidiata* (Loew) | Diptera | Tipulidae | predator | James (1952) |
| *Cirsium arvense* (L.). Scopoli (*Asteraceae*) | *Urophora cardui* L. | Diptera | Tephritidae | phytophage | Laing (1978) |
| *Cirsium vulgare* (Savi) Tenore (*Asteraceae*) | *Rhinocyllus conicus* Frölich | Coleoptera | Curculionidae | | Laing & Heels (1979) |
| *Closterotomus norvegicus* (Gmelin) [=*Calocoris norvegicus* Reuters] (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Coleomegilla maculata lengi* Timberlake (Coleoptera: Coccinellidae) | *Dinocampus coccinellae* (Schrank) [=*Perilitus coccinellae* (Shrank)] | Hymenoptera | Braconidae | parasitoid | Wright (1979); Wright & Laing (1979) |
| *Coleophora alcyonipennella* (Kollar) (Lepidoptera: Coleophoridae) | *Neochrysocharis formosus* (Westwood) [=*Neochrysocharis formosa* (Westwood)] | Hymenoptera | Eulophidae | parasitoid | Ellis & Bjørnson (1996) |
| *Coleophora deauratella* Lienig & Zeller (Lepidoptera: Coleophoridae) | *Bracon pygmaeus* Provancher | Hymenoptera | Braconidae | parasitoid | Ellis & Bjørnson (1996) |
| | *Neochrysocharis formosus* (Westwood) [=*Neochrysocharis formosa* (Westwood)] | Hymenoptera | Eulophidae | parasitoid | Ellis & Bjørnson (1996) |
| | *Neochrysocharis trifolii* Erdös [=*Chrysonotomyia trifolii* (Erdös)] | Hymenoptera | Eulophidae | parasitoid | Ellis & Bjørnson (1996) |
| *Coleophora laricella* (Hübner) (Lepidoptera: Coleophoridae) | *Agathis pumila* (Ratzeburg) | Hymenoptera | Braconidae | parasitoid | Graham (1958) |
| | *Chrysocharis laricinellae* (Ratzeburg) | Hymenoptera | Eulophidae | parasitoid | Graham (1958) |
| *Coleophora mayrella* (Hübner) (Lepidoptera: Coleophoridae) | *Neochrysocharis formosus* (Westwood) [=*Neochrysocharis formosa* (Westwood)] | Hymenoptera | Eulophidae | parasitoid | Ellis & Bjørnson (1996) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Coleophora pruniella* (Clemens) (Lepidoptera: Coleophoridae) | *Orgilus scaber* Muesebeck [=*Orgilus scabriculus* Nees] | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| *Coleophora tiliaefoliella* Clemens (Lepidoptera: Coleophoridae) | *Gelis* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Scambus decorus* Walley | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Scambus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| *Conotrachelus geminatus* LeConte (Coleoptera: Curculionidae) | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae) | *Hippodamia tredecimpunctata tibialis* (Say) | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| *Cotesia melanoscela* (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)] (Hymenoptera: Braconidae) | *Gelis tenellus* (Say) | Hymenoptera | Ichneumonidae | hyperparasitoid | Griffiths (1980); Song (1990) |
| *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) | *Baryscapus galactopus* (Ratzeburg) | Hymenoptera | Eulophidae | hyperparasitoid | Carter & Laing (1997) |
| | *Catolaccus* sp. | Hymenoptera | Pteromalidae | hyperparasitoid | Carter & Laing (1997) |
| | *Mesochorus vittator* (Zetterstedt) | Hymenoptera | Ichneumonidae | hyperparasitoid | Carter & Laing (1997) |
| *Craponius inaequalis* (Say) (Coleoptera: Curculionidae) | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Culex annulirostris* Skuse (Diptera: Culicidae) | *Paracleius germanus* Parent | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| *Culex pipiens* L. (Diptera: Culicidae) | *Dugesia tigrina* (Girard) | Tricladida | Duegesiidae | predator | George (1979; 1984) |
| *Culex quinquefasciatus* Say (Diptera: Culicidae) | *Paracleius germanus* Parent | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| *Culex restuans* Theobald (Diptera: Culicidae) | *Dolichopus gratus* Loew | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Dugesia tigrina* (Girard) | Tricladida | Duegesiidae | predator | George (1979; 1984) |
| *Cydia pomonella* (L.) [=*Carpocapsa pomonella* (L.)] (Lepidoptera: Tortricidae) | *Agelena naevia* Walckenaer | Araneae | Agelenidae | predator | Putnam (1963) |
| | *Anystis agilis* Banks | Trombidiformes | Anystidae | predator | Putnam (1963) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Ascogaster quadridentata* Wesmael [=*Ascogaster carpocapsae* (Viereck)] | Hymenoptera | Braconidae | parasitoid | Putnam (1963) |
| | *Bacillus cereus* Frankland & Frankland | | Bacillaceae | pathogen | Angus & Heimpel (1960); Putnam (1963) |
| | *Beauveria bassiana* (Balsamo) Vuillemin | | Moniliaceae | pathogen | Putnam (1963) |
| | *Chrysopa carnea* Stephens [=*Chrysops plorabunda* Fitch] | Neuroptera | Chrysopidae | predator | Putnam (1963) |
| | *Chrysopa rufilabris* Burmeister | Neuroptera | Chrysopidae | predator | Putnam (1963) |
| | *Cryptus albitarsis* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Dendrocops pubescens* (L.) | Piciformes | Picidae | predator | Putnam (1963) |
| | *Dendrocops villosus* (L.) | Piciformes | Picidae | predator | Putnam (1963) |
| | *Dibrachys microgastri* (Bouché) [=*Dibrachys cavus* (Walker) =*Dibrachys boucheanus* (Ratzeburg)] | Hymenoptera | Pteromalidae | parasitoid | Putnam (1963) |
| | *Elodia tragica* (Meigen) | Diptera | Tachindae | parasitoid | Putnam (1963) |
| | *Eupelmus cyaniceps* Ashmead | Hymenoptera | Eupelmidae | parasitoid | Putnam (1963) |
| | *Eurytoma* sp. | Hymenoptera | Eurytomidae | parasitoid | Putnam (1963) |
| | *Glypta* sp. | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Haplothrips faurei* Hood | Thysanoptera | Phaelothripidae | predator | Putnam (1963) |
| | *Hirsutella subulata* Petch | | Ophiocordycipitaceae | pathogen | Putnam (1963) |
| | *Hoplocryptus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Hyaliodes vitripennis* (Say) | Hemiptera | Miridae | predator | Putnam (1963) |
| | *Hymenochaonia delicata* (Cresson) [=*Macrocentrus delicatus* Cresson] | Hymenoptera | Braconidae | parasitoid | Putnam (1963) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Leptothrips mali* (Fitch) | Thysanoptera | Phaelothripidae | predator | Putnam (1963) |
| | *Liotryphon caudatus* (Ratzeburg) [=*Apistephialtes caudatus* (Ratzeburg)] | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Macrocentrus ancylivora* Rohwer | Hymenoptera | Braconidae | parasitoid | Putnam (1963) |
| | *Macrocentrus instabilis* Muesebeck | Hymenoptera | Braconidae | parasitoid | Putnam (1963) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Mastrus carpocapsae* (Cushman) [=*Aenoplex carpocapsae* Cushman] | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Mermis* sp. | Mermithida | Mermithidae | parasite | Putnam (1963) |
| | *Neoaplectana* n. sp. | Rhabditida | Steinernematidae | parasite | Putnam (1963) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| | *Nippocryptus vittatorius* (Jurine) [=*Cryptus sexannulatus* Gravenhorst] | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Nosema destructor* Steinhaus & Hughes | | Nosematidae | pathogen | Putnam (1963) |
| | *Panonychus ulmi* Koch | Trombidiformes | Tetranychidae | predator | Hagley (1979) |
| | *Phanerotoma fasciata* Provancher | Hymenoptera | Braconidae | parasitoid | Putnam (1963) |
| | *Pimpla annulipes* Brullé [=*Pimpla inflata* Townes] | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Plistophora californica* Steinhaus & Hughes | | Nosematidae | pathogen | Putnam (1963) |
| | *Pristomerus vulnerator* (Panzer) | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Scambus pterophori* Ashmead [=*Pimpla pterela* Auctorum] | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Solenopsis molesta* (Say) | Hymenoptera | Formicidae | predator | Putnam (1963) |
| | *Temelucha minor* (Cushman) | Hymenoptera | Ichneumonidae | parasitoid | Putnam (1963) |
| | *Tenebroides corticalis* Melsheimer | Coleoptera | Trogossitidae | predator | Putnam (1963) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley (1987); Hagley & Laing (1989) |
| | *Trichogramma minutum* Riley [=*Trichogramma emryophagum* Hertig] | Hymenoptera | Trichogrammatidae | parasitoid | Putnam (1963) |
| | *Trichogramma pretiosum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley (1987); Hagley & Laing (1989) |
| | *Trichogramma* sp. | Hymenoptera | Trichogrammatidae | parasitoid | Putnam (1963) |
| *Cylindrocopturus adspersus* (LeConte) (Coleoptera: Curculionidae) | *Anaphes pallipes* (Ashmead) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Cylindrocopturus furnissi* Buchanan (Coleoptera: Curculionidae) | *Dinotiscus dendroctoni* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| *Dasyneura albovittata* Walsh (Diptera: Cecidomyiidae) | *Ceraphron* sp. | Hymenoptera | Ceraphronidae | parasitoid | Judd (1953) |
| | *Leptacis* sp. | Hymenoptera | Platygasteridae | parasitoid | Judd (1953) |
| | *Tetrastichus* sp. | Hymenoptera | Eulophidae | parasitoid | Judd (1953) |
| | *Torymus* sp. | Hymenoptera | Torymidae | parasitoid | Judd (1953) |
| *Delia antiqua* (Meigen) [=*Hylemya antiqua* Meigen] (Diptera: Anthomyiidae) | *Aleochara bilineata* Gyllenhal | Coleoptera | Staphylinidae | parasitoid | Whistlecraft & Lepard (1989) |
| | *Aphaereta pallipes* (Say) | Hymenoptera | Braconidae | parasitoid | Whitfield et al. (1981); Whistlecraft & Lepard (1989) |
| | *Entomophthora muscae* (Cohn) Fresen | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| *Delia radicum* (L.) [=*Hylemya brassicae* L.] (Diptera: Anthomyiidae) | *Heterotylenchus* sp. | Nematoda | Sphaerulariidae | parasite | Wright (1972) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch & Briand (1961); Welch (1962) |
| *Delia* spp. [=*Hylemya* spp.] (Diptera: Anthomyiidae) | *Phygadeuon trichops* Thomson | Hymenoptera | Ichneumonidae | parasitoid | Maybee (1956) |
| *Dendroctonus frontalis* Zimmermann (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Dendroctonus* spp. (Coleoptera: Curculionidae) | *Dinotiscus dendroctoni* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| *Diabrotica barberi* R.F. Smith & Lawrence [=*Diabrotica longicornis* (Say)] (Coleoptera: Chrysomelidae) | *Agonum muelleri* (Herbst) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Amara avida* Say | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Amara* sp. | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Anisodactylus rusticus* (Say) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Anisodactylus sanctaecrucis* (Fabricius) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Bembidion quadrimaculatum oppositum* Say | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Bembidion tetracolum* Say | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Bembidion versicolor* (LeConte) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Blemus discus* (Fabricius) [=*Lasiotrechus discus* Fabricius] | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Carabus nemoralis* Müller | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Clivina fossor* (L.) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Colliuris pensylvanica* L. | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Dyschirius* sp. | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Harpalus affinis* (Schrank) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Harpalus pensylvanicus* (DeGeer) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Harpalus pleuriticus* Kirby | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Notiophilus aquaticus* (L.) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Patrobus longicornis* (Say) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Poecilus lucublandus* (Say) [=*Pterostichus lucublandus* Say] | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Pterostichus melanarius* (Illiger) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Stenolophus comma* (Fabricius) | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Tachys* sp. | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| | *Trechus apicalis* Motschulsky | Coleoptera | Carabidae | predator | Tyler & Ellis (1980) |
| *Diabrotica trivitta* (Mannerheim) (Coleoptera: Chrysomelidae) | *Howardula beninga* Cobb | Tylenchida | Allantonematidae | parasite | Briand (1960) |
| *Dibolia borealis* Chevrolat (Coleoptera: Chrysomelidae) | *Anaphes behmani* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Diprion hercyniae* (Hartig) (Hymenoptera: Diprionidae) | *polyhedrosis virus NPV* | | *Baculoviridae* | pathogen | Bird et al. (1973) |
| *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) | *Basalys tritomus* Thomson [=*Loxotropa tritoma* (Thomson)] | Hymenoptera | Diapriidae | parasitoid | Maybee (1956) |
| | *Zelus exsanguis* (Stål) | Orthoptera | Mantidae | predator | West & DeLong (1956) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Drosophila subobscura* Collin (Diptera: Drosophilidae) | *Parasitylenchus diplogenus* Welch | Tylenchida | Allantonematidae | parasite | Welch (1962) |
| *Elasmopalpus lingosellus* (Zeller) (Lepidoptera: Pyralidae) | *Trachagathis rubricincta* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Sharkey (2007) |
| *Empoasca fabae* Harris (Hemiptera: Cicadellidae) | *Anagrus armatus* (Ashmead) | Hymenoptera | Mymaridae | parasitoid | Appleton et al. (2004) |
| | *Zoophthora radicans* (Brefeld) Batko [=*Erynia radicans* (Brefeld) Humber, Ben-Ze'ev & Kenneth] | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Zoophthora radicans* (Brefeld) Batko [ *Erynia radicans* (Brefeld)] | | Entomophthoraceae | pathogen | Appleton et al. (2004) |
| *Ephestia kuehniella* Zeller [=*Anagasta kuhniella* (Zeller)] (Lepidoptera: Pyralidae) | *Bacillus thuringiensis* Berliner serovar. *thuringiensis* | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Laing (1989); Corrigan & Laing (1992); Corrigan et al. (1994) |
| | *Trichogramma pretiosum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Laing (1989) |
| *Epiblema scudderiana* (Clemens) (Lepidoptera: Tortricidae) | *Apanteles cacoeciae* Riley [ *Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| | *Bassus binominatus* (Muesebeck) [ *Agathis binominata* Muesebeck] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| | *Macrocentrus pallisteri* DeGant | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| | *Perilampus fulvicornis* Ashmead | Hymenoptera | Perilampidae | hyperparasitoid | Laing & Heraty (1982) |
| | *Scambus pterophori* Asmead | Hymenoptera | Ichneumonidae | parasitoid | Laing & Heraty (1982) |
| *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae) | *Glypta rufiscutellaris* Cresson | Hymenoptera | Ichneumonidae | parasitoid | Boyce & Dustan (1954) |
| *Epinotia* sp. (Lepidoptera: Tortricidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Eriosoma lanigerum* (Hausmann) (Hemiptera: Aphididae) | *Aphelinus mali* Haldeman | Hymenoptera | Aphelinidae | parasitoid | Hagley & Laing (1989) |
| *Euphorbia esula* L. (*Euphorbiaceae*) | *Aphthona czwalinae* Weise | Coleoptera | Chrysomelidae | phytophage | LeSage (1996a) |
| | *Aphthona flava* Guillebeau | Coleoptera | Chrysomelidae | phytophage | LeSage (1996a) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Aphthona nigriscutis* Foudras | Coleoptera | Chrysomelidae | phytophage | LeSage (1996a) |
| *Eurosta solidaginis* (Fitch) (Diptera: Tephritidae) | *Eurytoma obtusiventris* Gahan | Hymenoptera | Eurytomidae | parasitoid | Ramey (1990) |
| *Exartema* sp. (Lepidoptera: Tortricidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Exeristes comstockii* (Cresson) (Diptera: Tachinidae) | *Trichomalopsis viridescens* (Walsh) | Hymenoptera | Pteromalidae | parasitoid | Murillo et al. (2012) |
| *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) | *Neoseiulus cucumeris* (Oudemans) [=*Amblyseius cucumeris* (Oudemans) | Mesostigmata | Phytoseiidae | predator | Jones et al. (2006) |
| *Gerris* sp. (Hemiptera: Gerridae) | *Anaphes gerrisophaga* (Doutt) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Gnorimoschema gallaesolidaginis* (Riley) (Lepidoptera: Gelechiidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Gorytes costalis* Cresson [=*Psammecius costalis* (Cresson)] (Hymenoptera: Crabronidae) | *Elampus viridicyaneus* Norton | Hymenoptera | Chrysididae | parasitoid | Huber & Pengelly (1977) |
| *Grapholita molesta* (Busck) [=*Grapholitha molesta* (Busck)] (Lepidoptera: Tortricidae) | *Enytus obliteratus* (Cresson) [=*Diadegma obliteratum* (Cresson)] | Hymenoptera | Ichneumonidae | parasitoid | Boyce & Dunstan (1954); Dunstan & Boyce 1966) |
| | *Glypta rufiscutellaris* Cresson | Hymenoptera | Ichneumonidae | parasitoid | Boyce & Dustan (1954); Dustan & Boyce (1966) |
| | *Hymenochaonia delicata* (Cresson) [=*Macrocentrus delicatus* Cresson] | Hymenoptera | Braconidae | parasitoid | Boyce & Dunstan (1954); Dunstan & Boyce 1966) |
| | *Macrocentrus ancylivora* Rohwer | Hymenoptera | Braconidae | parasitoid | Boyce & Dustan (1954); Dustan & Boyce (1966); Philips (1969) |
| | *Temelucha minor* (Cushman) [=*Cremastus minor* Cushman] | Hymenoptera | Ichneumonidae | parasitoid | Boyce & Dustan (1954); Dustan & Boyce (1966) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley (1987) |
| grasshoppers (Orthoptera: Acrididae) | *Pseudomonas aeruginosa* (Schroeter) Migula | | Bacillaceae | pathogen | Angus & Heimpel (1960) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Hedya chionosema* (Zeller) (Lepidoptera: Tortricidae) | *Macrocentrus nigridorsis* Viereck | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| *Hedya nubiferana* (Haworth) (Lepidoptera: Tortricidae) | *Cotesia acauda* (Provancher) [=*Cotesia acaudus* Provancher] | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |
| *Heliothis* spp. (Lepidoptera: Noctuidae) | *Trichogramma pretiosum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Laing (1989) |
| *Helioverpa virescens* (Fabricius) [=*Heliothis virescens* (Fabricius)] (Lepidoptera: Noctuidae) | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| *Hyalopsocus striatus* (Walker) (Psocoptera: Psocidae) | *Leiophron* (*Euphoriella*) *criddlei* (Loan & New) [=*Euphoriella criddlei* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron foutsi* (Loan & New) [=*Euphoriella foutsi* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron hyalopsocidis* (Loan & New) [=*Euphoriella hyalopsocidis* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron incerta* (Ashmead) [=*Euphoriella incerta* Ashmead] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron kaladarensis* (Loan & New) [=*Euphoriella kaladarensis* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron nixoni* (Loan & New) [=*Euphoriella nixoni* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron pacifica* (Muesebeck) [=*Euphoriella pacifica* Muesebeck] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron pallidifacia* (Loan & New) [=*Euphoriella pallidifacia* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron solidaginis* (Loan & New) [=*Euphoriella solidaginis* Loan & New] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| | *Leiophron sommermanae* (Muesebeck) [=*Euphoriella sommermanae* Muesebeck] | Hymenoptera | Braconidae | parasitoid | Loan & New (1972) |
| *Hydraecia micacea* (Esper) (Lepidoptera: Noctuidae) | *Campoletis* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Centrodora* near *locustrum* Girault | Hymenoptera | Aphelinidae | parasitoid | West et al. (1984) |
| | *Diadegma* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Epirus* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Exephanes occupator* Gravenhorst | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Glypta* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Lydella radicis* (Townsend) | Diptera | Tachinidae | parasitoid | West et al. (1984) |
| | *Lydella stabulans* (Meigen) | Diptera | Tachinidae | parasitoid | West et al. (1984) |
| | *Macrocentrus blandus* Eady & Clark | Hymenoptera | Braconidae | parasitoid | West et al. (1984) |
| | *Macrocentrus infirmus* (Nees) | Hymenoptera | Braconidae | parasitoid | West et al. (1984) |
| | *Pterocormus* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Telenomus* sp. | Hymenoptera | Scelionidae | parasitoid | West et al. (1984) |
| | *Therion* sp. | Hymenoptera | Ichneumonidae | parasitoid | West et al. (1984) |
| | *Trichogramma retorridum* (Girault) | Hymenoptera | Trichogrammatidae | parasitoid | West et al. (1984) |
| *Hypera brunneipennis* (Boheman) (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera compta* (Say) (Coleoptera: Curculionidae) | *Anaphes nigrellus* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Hypera crinitus* (Boheman) [=*Donus crinitus* Boehman] (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera eximia* (LeConte) (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| | *Anaphes nigrellus* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Hypera nigrirostris* (Fabricius) (Coleoptera: Curculionidae) | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera paludicola* Warner (Coleoptera: Curculionidae) | *Anaphes nigrellus* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Hypera postica* (Gyllenahl) (Coleoptera: Curculionidae) | *Anaphes fuscipennis* Haliday | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| | *Anaphes nigrellus* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Bathyplectes anurus* (Thomson) | Hymenoptera | Ichneumonidae | parasitoid | Harcourt & Ellis (1992) |
| | *Bathyplectes curculionis* (Thomson) | Hymenoptera | Ichneumonidae | parasitoid | Abu & Ellis (1976); Harcourt & Ellis (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Beauveria bassiana* (Balsamo) Vuillemin | | Moniliaceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Entomophthora* (*Tarichium*) *punctata* Garbowski | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Entomophthora phytonomi* Arthur | | Entomophthoraceae | pathogen | Harcourt et al. (1980) |
| | *Erynia phytonomi* (Arthur) Humber, Ben-Ze'ev & Kenneth | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Erynia* sp. | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Perilitus aethiops* Nees [=*Microctonus aethiopoides* Loan | Hymenoptera | Braconidae | parasitoid | Harcourt et al. (1980; 1982); Loan (1982) |
| | *Perilitus colesi* (Drea) [=*Microctonus colesi* Drea | Hymenoptera | Braconidae | parasitoid | Harcourt et al. (1982); Loan (1982) |
| | *Tarichium phytonomi* Jaczewski | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Zoophthora phytonomi* (Arthur) Batko | | Entomophthoraceae | pathogen | Harcourt & Ellis (1992) |
| | *Zoophthora* spp. | | Entomophthoraceae | pathogen | Loan (1982) |
| *Hypera punctata* (Fabricius) (Coleoptera: Curculionidae) | *Anaphes fuscipennis* Haliday | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera trilineata* Marsham (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera variabilis* Herbst (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypera zoilus* Scopoli (Coleoptera: Curculionidae) | *Anaphes luna* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Hypericum perforatum* L. (*Hyperiaceae*) | *Chrysolina hyperici* (Förster) | Coleoptera | Chrysomelidae | phytophage | LeSage (1996b) |
| *Hyraecia petasitis* Doubleday (Lepidoptera: Noctuidae) | *Macrocentrus blandus* Eady & Clark | Hymenoptera | Braconidae | parasitoid | West et al. (1984) |
| *Ips calligraphis* (Germar) (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Ips grandicollis* (Eichhoff) (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Ips pini* (Say) (Coleoptera: Curculionidae) | *Rhopalicus tutela* (Walker) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Ips* spp. (Coleoptera: Curculionidae) | *Dinotiscus dendroctoni* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| *Labops hirtus* Knight (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Lasius neoniger* Emery (Hymeoptera: Formicidae) | *Pseudometagea schwarzii* (Ashmead) | Hymenoptera | Eucharitidae | parasitoid | Heraty (1985) |
| *Lasius* sp. (Hymenoptera: Formicidae) | *Pseudometagea schwarzii* (Ashmead) | Hymenoptera | Eucharitidae | parasitoid | Heraty (1985) |
| *Lebia vittata* (Fabricius) [=*Diabrotica vittata* (Fabricius)] (Coleoptera: Chrysomelidae) | *Howardula beninga* Cobb | Tylenchida | Allantonematidae | parasite | Briand (1960) |
| *Lema cyanella* (L.) (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Lema lichenis* Voet (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Lema trilineata* (Olivier) (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1993) |
| *Lema trivittata trivittata* (Say) [=*Lema trilineata trivittata* (Say)] (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1994) |
| *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Stewart et al. (1992) |
| | *Horismenus puttleri* (Grissell) [=*Edovum puttleri* Grissell] | Hymenoptera | Eulophidae | parasitoid | Corrigan et al. (1990) |
| | *Neoaplectana chresima* Steiner | Rhabditida | Steinernematidae | parasite | Welch (1958) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch & Briand (1961); Welch (1962) |
| *Leptopterna dolobrata* (L.) (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Lestes* sp. (Odonata: Lestidae) | *Anaphes gerrisophaga* (Doutt) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Lioligus nitidus* (Motschulsky) (Coleoptera: Byrridae) | *Anaphes byrrhidiphagus* Huber | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Lioon simplicipes* (Mannerheim) (Coleoptera: Byrridae) | *Anaphes byrrhidiphagus* Huber | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Liriomyza sativae* Blanchard (Diptera: Agromyzidae) | *Diglyphus intermedius* (Girault) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987b) |
| *Liriomyza trifoliearum* Spencer [=*Liriomyza trifolearum* Spencer] (Diptera: Agromyzidae) | *Diglyphus intermedius* (Girault) | Hymenoptera | Eulophidae | parasitoid | Coote & Ellis (1987b) |
| *Listronotus oregonensis* (LeConte) (Coleoptera: Curculionidae) | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Lygus hesperus* Knight (Hemiptera: Miridae) | *Geocoris pallens* Stâhl | Hemiptera | Geocoridae | predator | Mason et al. (2011) |
| | *Geogoris punctipes* (Say) | Hemiptera | Geocoridae | predator | Mason et al. (2011) |
| | *Nabis alternatus* Parshley | Hemiptera | Nabidae | predator | Mason et al. (2011) |
| | *Nabis americoferus* (Carayon) | Hemiptera | Nabidae | predator | Mason et al. (2011) |
| | *Orius tristicolor* (White) | Hemiptera | Anthocoridae | predator | Mason et al. (2011) |
| *Lygus lineolaris* (Palisot) [=*Liocoris lineolaris* (Beauvois)] | *Leiophron pseudopallipes* (Loan) [=*Peristenus pseudopallipes* Loan | Hymenoptera | Braconidae | parasitoid | Broadbent et al. (1999); Mason et al. (2011) |
| | *Leiophron dayi* (Goulet) [=*Peristenus dayi* Goulet] | Hymenoptera | Braconidae | parasitoid | Mason et al. (2011) |
| | *Leiophron digoneutis* (Loan) [=*Peristenus digoneutis* Loan] | Hymenoptera | Braconidae | parasitoid | Broadbent et al. (1999); Mason et al. (2011) |
| | *Leiophron lygivora* (Loan) | Hymenoptera | Braconidae | parasitoid | Broadbent et al. (1999); Mason et al. (2011) |
| | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965); Broadbent et al. (1999); Mason et al. (2011) |
| | *Leiophron rubricollis* (Thomson) [=*Peristenus rubricollis* (Thomson) =*Peristenus conradi* Marsh] | Hymenoptera | Braconidae | parasitoid | Broadbent et al. (1999); Mason et al. (2011) |
| | *Leiophron uniformis* (Gahan) | Hymenoptera | Braconidae | parasitoid | Broadbent et al. (1999) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Lygus* spp. (Hemiptera: Miridae) | *Anaphes iole* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Lymantria dispar* (L.) [=*Porthetria dispar* L.] (Lepidoptera: Erebidae) | *Bacillus thuringiensis* Berliner serovar. *kurstaki* | | Bacillaceae | pathogen | Cunningham et al. (1996a; b) |
| | *Ceranthia samarensis* (Villeneuve) | Diptera | Tachinidae | parasitoid | Nealis & Quendau (1996) |
| | *Compsilura concinnata* (Meigen) | Diptera | Tachinidae | parasitoid | Griffiths (1977) |
| | *Cotesia melanoscela* (Ratzeburg) | Hymenoptera | Braconidae | parasitoid | Nealis & Bourchier (1995) |
| | *Cotesia melanoscela* (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)] | Hymenoptera | Braconidae | parasitoid | Griffiths (1976) |
| | *Ooencyrtus kuvanae* (Howard) | Hymenoptera | Encyrtidae | parasitoid | Hagley & Laing (1989) |
| | *Parasetigena agilis* (Robineau-Desvoidy) | Diptera | Tachinidae | parasitoid | Griffiths (1978) |
| | *Pimpla pedalis* Cresson | Hymenoptera | Ichneumonidae | parasitoid | Griffiths (1979) |
| | *Pleistophora schubergi* Zwölfer | | Pleistophoridae | pathogen | Wilson (1985a) |
| *Lythrum salicaria* L. (*Lythraceae*) | *Neogalerucella calmariensis* (L.) [=*Galerucella calmariensis* (L.)] | Coleoptera | Chrysomelidae | phytophage | Corrigan et al. (1998) |
| *Macrocentrus* spp. (Hymenoptera: Braconidae) | *Eupelmus cyaniceps* Ashmead | Hymenoptera | Eupelmidae | hyperparasitoid | Putnam (1963) |
| *Macrosteles fascifrons* (Stål) (Hemiptera: Cicadellidae) | *Epigonatopus plesius* Fenton | Hymenoptera | Dryinidae | parasitoid | Miller & De Lyzer (1960) |
| *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae) | *Aleiodes malacosomatos* (Mason) [=*Rogas malacosomatos* Mason] | Hymenoptera | Braconidae | parasitoid | Harmsen & Rose (1984) |
| | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Angus (1965) |
| | *Nosema disstriae* Thompson | | Nosematidae | pathogen | Wilson (1980) |
| | *Phobocampe clisiocampae* (Weed) | Hymenoptera | Ichneumonidae | parasitiod | Harmsen & Rose (1984) |
| | *Vairimorpha necatrix* (Kramer) | Dissociodihaplo-phasida | Nosematidae | pathogen | Wilson (1987) |
| | *Zelus exsanguis* (Ståhl) | Orthoptera | Mantidae | predator | West & DeLong (1956) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Marmara fraxinicola* Braun (Lepidoptera: Gracilariidae) | *Ageniaspis bicoloripes* (Girault) [=*Paraleurocerus bicoloripes* Girault] | Hymenoptera | Encyrtidae | parasitoid | Wang & Laing (1989) |
| *Melolontha* spp. (Coleoptera: Scarabaeidae) | nematode | Nematoda | | parasite | Welch (1962) |
| *Meteorus hyphantriae* Riley [=*Meteorus hyphantria* Riley] (Hymenoptera: Ichneumonidae) | *Gelis* sp. | Hymenoptera | Ichneumonidae | hyperparasitoid | Pengelly (1961) |
| *Morellia hortorum* (Fallén) (Diptera: Muscidae) | *Heterotylenchus* sp. | Nematoda | Sphaerulariidae | parasite | Wright (1972) |
| *Musca autumnalis* DeGeer (Diptera: Muscidae) | *Heterotylenchus autumnalis* Nickle | Nematoda | Sphaerulariidae | parasite | Gregory & Wright (1973); Wright (1972) |
| | *Entomophthora* sp. | | Entomophthoraceae | pathogen | Gregory & Wright (1973) |
| *Musca vetutissima* Walker (Diptera: Muscidae) | *Heterotylenchus* sp. | Nematoda | Sphaerulariidae | parasite | Wright (1972) |
| *Mythima unipuncta* (Haworth) [=*Pseudaletia unipuncta* (Haworth)] (Lepidoptera: Noctuidae) | *Apanteles* sp. | Hymenoptera | Braconidae | parasitoid | Goble (1965) |
| | *Betabaculovirus* sp. [=*Borrelinavirus* sp.] | | *Baculoviridae* | disease | Goble (1965) |
| | *Winthemia* sp. | Diptera | Tachinidae | parasitoid | Goble (1965) |
| *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) | *Entomophthora planchoniana* Cornu | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| *Nabis capsiformis* Germar [=*Reduviolus capsiformis* (Germar); *Reduviolus blackburni* (Kirkaldy)] (Hemiptera: Nabidae) | *Stephanodes reduvioli* (Perkins) | Hymenoptera | Mymaridae | parasitoid | Huber & Fildago (1997) |
| *Neodiprion lecontei* (Fitch) (Hymenoptera: Diprionidae) | *Lecontvirus* (*redheaded pine sawfly NPV*) | | *Baculoviridae* | pathogen | Cunnigham et al. (1987) |
| *Neodiprion pratti banksianae* Rohwer [=*Neodiprion banksiana*] (Hymenoptera: Diprionidae) | *polyhedrosis virus* | | *Baculoviridae* | pathogen | Cameron (1969) |
| *Neodiprion sertifer* (Geoffroy) (Hymenoptera: Diprionidae) | *Pleolophus basizonus* (Gravenhorst) | Hymenoptera | Ichneumonidae | parasitoid | Griffiths (1972) |
| | *polyhedrosis virus* | | *Baculoviridae* | pathogen | Cameron (1969) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *polyhedrosis virus NPV* | | *Baculoviridae* | pathogen | Bird et al. (1973) |
| *Notoxus anchora* Hentz (Coleoptera: Anthicidae) | *Centistes agilis* (Cresson) [=*Syrrhizus agilis* (Cresson)] | Hymenoptera | Braconidae | parasitoid | Loan (1973) |
| *Nycteola cinereana* Neumoegen & Dyar [= *Sarrothripus cinereana* Neumoegen & Dyar] (Lepidoptera: Nolidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Angus (1965) |
| *Nymphalis antiopa* (L.) (Lepidoptera: Nymphalidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Angus (1965) |
| *Orocrambus simplex* Butler [=*Crambus simplex* Butler] (Lepidoptera: Crambidae) | *Neoaplectana leucaniae* Hoy | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae) | *Neoaplectana glaseri* Steiner | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| *Oscinella frit* (L.) (Diptera: Chloropidae) | *Basalys tritomus* (Thomson) [=*Loxotropa tritoma* (Thomson)] | Hymenoptera | Diapriidae | parasitoid | Maybee (1956) |
| *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae) | *Autographa californica NPV* (ACNPV) | | *Baculoviridae* | pathogen | Laing & Jacques (1985) |
| | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Laing & Jacques (1985) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch & Briand (1961); Welch (1962) |
| | *Nosema heliothidis* Lutz & Splendor | | Nosematidae | pathogen | Wilson (1985a) |
| | *Nosema pyrausta* (Paillot) | | Nosematidae | pathogen | Laing & Jacques (1985) |
| | *Vairimorpha necatrix* (Kramer) | | Nosematidae | pathogen | Laing & Jacques (1985) |
| *Oulema collaris* (Say) (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Oulema gallaeciana* (Heydon) (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae) | *Anaphes flavipes* (Förster) | Hymenoptera | Mymaridae | parasitoid | Ellis et al. (1989); Huber (1992) |
| | *Tetrastichus julis* (Walker) | Hymenoptera | Eulophidae | parasitoid | Ellis et al. (1979; 1989) |
| *Pandemis* sp. (Lepidoptera: Tortricidae) | *Triclistus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Panonychus ulmi* (Koch) [=*Metatetranychus ulmi* (Koch)] (Trombidiformes: Tetranychidae) | *Adalia bipunctata* (L.) | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Amblyseius* spp. | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Balaustium putnami* Smiley | Trombidiformes | Erythraeidae | predator | Cadogan & Laing (1982) |
| | *Balaustium* sp. | Trombidiformes | Erythraeidae | predator | Woolhouse & Harmsen (1985) |
| | *Neoseiulus cucumeris* (Oudemans) [=*Typhlodromus cucumeris* Oudemans] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Neoseiulus fallacis* (Garman) [=*Typhlodromus fallacis* (Garman)] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Phytoseius macropilis* (Banks) | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus bakeri* (Garman) [=*Typhlodromus (Neoseiulus) bakeri* (Garman)] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus caudiglans* (Schuster) | Mesostigmata | Phytoseiidae | predator | Clements (1989) |
| | *Typhlodromus conspicuus* (Garman) | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus conspicuus* var. *herbertae* Nesbitt | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus finlandicus* (Oudemans) [=*Typhlodromus finlandicus* Oudemans] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus longipilus* Nesbitt | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus masseei* (Nesbitt) [=*Typhlodromus masseei* Nesbitt] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus pomi* (Parrott, Hodgkiss & Shoene) [=*Typhlodromus pomi* (Parrott) Garman] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus rhenanus* (Oudemans) [=*Typhlodromus (Neoseiulus) rhenanus* Oudemans] | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus tiliae* Oudemans | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Typhlodromus tiliarum* (Garman) | Mesostigmata | Phytoseiidae | predator | Herbert (1953) |
| | *Zetzellia mali* (Ewing) | Trombidiformes | Stigmaeidae | predator | Clements (1989) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Periplaneta americana* (L.) (Orthoptera: Blattidae) | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | Edwards & Pengelly (1966) |
| *Philaenus spumarius* (L.) (Hemiptera: Cercopidae) | *Erynia petchii* (Ben-Ze'ev & Kenneth) | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Ooctonus vulgatus* Haliday | Hymenoptera | Mymaridae | parasitoid | Huber (2012) |
| *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) | *Chelonus kellieae* Marsh | Hymenoptera | Braconidae | parasitoid | Wang & Laing (1989) |
| | *Chelonus phthorimaeae* Gahan | Hymenoptera | Braconidae | parasitoid | Wang & Laing (1989) |
| *Phyllonorycter blancardella* (Fabricius) [=*Lithocolletis blancardella* Fabricius] (Lepidoptera: Gracillaridae) | *Achrysocharoides* sp. [=*Enaysma* sp.] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Ageniaspis testaceipes* (Ratzeburg) [=*Holcothorax testaceipes* (Ratzeburg)] | Hymenoptera | Encyrtidae | parasitoid | Wang & Laing (1989) |
| | *Baryscapus nigroviolaceus* (Nees) [=*Tetrastichus amethystinus* (Ratzeburg)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Chrysocharis nepereus* (Walker) [=*Chrysocharis cuspidogaster* Yoshimoto] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Chrysocharis pubens* Delucchi | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Cirrospilus elegantissimus* Westwood | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Cirrospilus lyncus* Walker [=*Atoposomoidea lyncus* Walker] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Cirrospilus lyncus* Walker [=*Atoposomoidea unifasciata* (Förster)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Closterocerus* sp. | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Copidosoma truncatellum* (Dalman) | Hymenoptera | Encyrtidae | parasitoid | Wang & Laing (1989) |
| | *Minotetrastichus frontalis* (Nees) [=*Tetrastichus cyclogaster* (Ratzeburg)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Minotetrastichus frontalis* (Nees) [=*Tetrastichus xanthops* (Ratzeburg)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Minotetrastichus platanellus* (Mercet) [=*Tetrastichus platanellus* (Mercet)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Neochrysocharis formosus* (Westwood) [=*Achrysocharella formosa* (Westwood)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Pediobius saulius* (Walker) | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Pholetesor circumscriptus* (Nees) [=*Apanteles blancardellae* Bouché] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pholetesor circumscriptus* (Nees) [=*Apanteles flavolimbatus* Ratz] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pholetesor circumscriptus* (Nees) [=*Apanteles lautellus* Marsh] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pholetesor circumscriptus* Nees [=*Apanteles circumscriptus* Nees] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pholetesor ornigis* (Weed) | Hymenoptera | Braconidae | parasitoid | Fisher (1988) |
| | *Pholetesor ornigis* (Weed) [=*Apanteles ornigis* Weed] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pholetesor pedias* (Nixon) | Hymenoptera | Braconidae | parasitoid | Fisher (1988) |
| | *Pholetesor pedias* (Nixon) [=*Apanteles bicolor* Nees] | Hymenoptera | Braconidae | parasitoid | Johnson et al. (1977) |
| | *Pnigalio minio* (Walker) [=*Pnigalio flavipes* (Ashmead)] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Pnigalio uroplatae* (Howard) | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Sympiesis dolicogaster* Ashmead | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Sympiesis gordius* (Walker) [=*Sympiesis marylandensis* Girault] | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Sympiesis gordius* Walker | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| | *Sympiesis sericeicornis* (Nees) | Hymenoptera | Eulophidae | parasitoid | Johnson et al. (1977) |
| *Phyllonorycter ringoniella* Matsumura (Lepidoptera: Gracillaridae) | *Ageniaspis testaceipes* (Ratzeburg) [=*Holcothorax testaceipes* (Ratzeburg)] | Hymenoptera | Encyrtidae | parasitoid | Wang & Laing (1989; 1990) |
| *Phyllophaga* spp. (Coleoptera: Scarabaeidae) | *Pelecinus polyturator* (Drury) | Hymenoptera | Pelecinidae | parasitoid | Bennett (2004) |
| *Pieris rapae* (L.) (Lepidoptera: Pieridae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Jaques (1971) |
| | *Compsilura concinnata* (Meigen) | Diptera | Tachindae | parasitoid | Harcourt (1963) |
| | *Cotesia glomerata* (L.) [=*Apanteles glomeratus* (L.)] | Hymenoptera | Braconidae | parasitoid | Harcourt (1963); West et al. (1984); Wang & Laing (1989) |
| | *Cotesia rubecula* (Marsh) [= *Apanteles rubecula* Marsh] | Hymenoptera | Braconidae | parasitoid | Wang & Laing (1989) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Cotesia rubecula* (Marshall) | Hymenoptera | Braconidae | parasitoid | Corrigan (1983); Carter & Laing (1997) |
| | *Helicobia rapax* (Walker) [ *Helocobia rapax* Walker] | Diptera | Sarcophagidae | parasitoid | Harcourt (1963) |
| | *Madremyia saundersii* (Williston) | Diptera | Tachindae | parasitoid | Harcourt (1963) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch & Briand (1961); Welch (1962) |
| | *Phryxe vulgaris* (Fallén) | Diptera | Tachindae | parasitoid | Harcourt (1963) |
| | *Pieris rapae GV* [=*P. rapae GV*] (PrGV) | | *Baculoviridae* | pathogen | Jaques (1971) |
| | *Pteromalus puparum* (L.) | Hymenoptera | Pteromalidae | parasitoid | Harcourt (1963) |
| | *Tetrastichus* sp. | Hymenoptera | Eulophidae | parasitoid | Corrigan (1983) |
| *Pimpla annulipes* Brullé (Hymenoptera: Ichneumonidae) | *Eupelmus cyaniceps* Ashmead | Hymenoptera | Eupelmidae | hyperparasitoid | Putnam (1963) |
| *Pissodes approximatus* Hopkins (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Pissodes nemorensis* Germar (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Pissodes strobi* (Peck) (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| | *Dolichomitus terebrans nubilipennis* (Viereck) [=*Dolichotomitus terebrans nubilipennis* (Viereck)] | Hymenoptera | Ichneumonidae | parasitoid | Wallace & Sullivan (1985) |
| | *Eurytoma pissodis* Girault | Hymenoptera | Eurytomidae | parasitoid | Wallace & Sullivan (1985) |
| | *Lonchaea corticis* Taylor | Diptera | Lonchaeidae | predator | Wallace & Sullivan (1985) |
| | *Ooctonus quadricarinatus* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2012) |
| | *Rhopalicus tutela* (Walker) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| *Plagiognathus brunneus* (Provancher) [=*Plagiognathus medicagus* Arrand] (Hemiptera: Miridae) | *Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis] | Hymenoptera | Braconidae | parasitoid | Loan (1965) |
| *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) | *Nosema plodiae* Kellen & Lindgren | | Nosematidae | pathogen | Wilson (1985a) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Plutella xylostella* (L.) [=*Plutella maculipennis* (Curtis)] (Lepidoptera: Plutellidae) | *Campoletis* sp. | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Conura albifrons* (Walsh) [=*Spilochalcis albifrons* (Walsh)] | Hymenoptera | Chalcididae | parasitoid | Harcourt (1963) |
| | *Diadegma insulare* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Bolter & Laing (1984) |
| | *Diadegma insulare* (Cresson) [ *Horogenes insularis* (Cresson)] | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Diadromus subtilicornis* (Gravenhorst) | Hymenoptera | Ichneumonidae | parasitoid | Bolter & Laing (1984) |
| | *Diadromus subtilicornis* (Gravenhorst) [= *Diadromus plutellae* (Ashmead)] | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Dibracys microgastri* (Bouché) [=*Dibrachys cavus* (Walker)] | Hymenoptera | Pteromalidae | parasitoid | Harcourt (1963) |
| | *Gelis tenellus* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Microplitis plutellae* Muesbeck | Hymenoptera | Braconidae | parasitoid | Harcourt (1963); Bolter & Laing (1984) |
| | *Oomyzus sokolowskii* (Kurdjumov) [=*Tetrastichus sokolowskii* Kurdjumov] | Hymenoptera | Eulophidae | parasitoid | Harcourt (1963) |
| | *Pteromalus* sp. near *phycidis* Ashmead [=*Habrocytus* sp. near *phycidis* Ashmead] | Hymenoptera | Pteromalidae | parasitoid | Harcourt (1963) |
| *Polygraphus* spp. (Coleoptera: Curculionidae) | *Dinotiscus dendroctoni* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| *Popillia japonica* Newman (Coleoptera: Scarabaeidae) | *Bacillus lentimorbus* Dutky | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| | *Bacillus popilliae* Dutky | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| | *Neoaplectana glaseri* Steiner | Rhabditida | Steinernematidae | parasite | Welch (1962) |
| *Pristiphora erichsonii* (Hartig) (Hymenoptera: Tenthredinidae) | *Bacillus cereus* Frankland & Frankland | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| *Pseudaletia unipuncta* (Haworth) (Lepidoptera: Noctuidae) | *Vairimorpha necatrix* (Kramer) | Dissociodihaplophasida | Nosematidae | pathogen | Wilson (1987) |
| *Pseudatomoscelis* sp. (Hemiptera: Miridae) | *Anaphes iole* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Pseudexentera mali* Freeman (Lepidoptera: Tortricidae) | *Diadegma* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| *Pseudosciaphila* sp. [=*Sciaphila* sp.] (Lepidoptera: Olethreutidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Psila rosae* (Fabricius) (Diptera: Psilidae) | *Aleochara sparsa* Heer | Coleoptera | Staphylinidae | parasitoid | Maybee (1954) |
| | *Basalys tritomus* Thomson [=*Loxotropa tritoma* (Thomson)] | Hymenoptera | Diapriidae | parasitoid | Maybee (1954; 1956) |
| | *Chorebus posticus* (Haliday) [=*Dacnusa gracilis* (Nees)] | Hymenoptera | Braconidae | parasitoid | Maybee (1954; 1956) |
| | *Kleidotoma* sp. | Hymenoptera | Eucoilidae | parasitoid | Maybee (1954) |
| *Rhabdophaga strobiloides* Walsh (Diptera: Cecidomyiidae) | *Copidosoma* sp. | Hymenoptera | Encyrtidae | parasitoid | Judd (1953) |
| | *Torymus cecidomyae* (Walker) [=*Torymus strobiloides* (Huber)] | Hymenoptera | Torymidae | parasitoid | Judd (1953) |
| | *Tridymus* sp. | Hymenoptera | Pteromalidae | parasitoid | Judd (1953) |
| *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae) | *Xenorhabdus nematophilus* (Poinar & Thomas) [=*Achromobacter nematophilus* Poinar & Thomas] | | Enterobacteriaceae | pathogen | Poinar et al. (1977) |
| | *Allonemobius fasciatus* (DeGeer) | Orthoptera | Gryllidae | predator | Monteith (1976) |
| | *Amblyseius fallacis* Garman | Mesostigmata | Phytoseiidae | predator | Hagley (1979) |
| | *Anaphes conotracheli* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| | *Anaphes pallipes* (Ashmead) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| | *Bacillus cereus* Frankland & Frankland | | Bacillaceae | pathogen | Poinar et al. (1977) |
| | *Calosoma calidum* (Fabricius) | Coleoptera | Carabidae | predator | Monteith (1976; 1977) |
| | *Diachasma alloeum* (Muesebeck) [=*Opius alloeus* Muesebeck] | Hymenoptera | Braconidae | parasitoid | Monteith (1978) |
| | *Diachasma ferrugineum* (Gahan) [=*Opius ferrugineus* Gahan] | Hymenoptera | Braconidae | parasitoid | Monteith (1978) |
| | *Diachasmimorpha mellea* (Gahan) [=*Opius melleus* Gahan] | Hymenoptera | Braconidae | parasitoid | Monteith (1978) |
| | *Enterobacter* sp. | | Enterobacteriaceae | pathogen | Poinar et al. (1977) |
| | *Escherichia coli* (Migula ) Castellani and Chalmers | | Enterobacteriaceae | pathogen | Poinar et al. (1977) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Forficula auricularia* L. | Dermaptera | Forficulidae | predator | Monteith (1976; 1977) |
| | *Geotrichium* sp. | | Endomycetaceae | pathogen | Poinar et al. (1977) |
| | *Gryllus pennsylvanicus* Burmeister | Orthoptera | Gryllidae | predator | Monteith (1976) |
| | *Harpalus pensylvanicus* (DeGeer) | Coleoptera | Carabidae | predator | Monteith (1976; 1977) |
| | *Lithobius forficatus* (L.) | Lithobiomorpha | Lithobiidae | predator | Monteith (1976; 1977) |
| | *Neoaplectana* sp. | Rhabditida | Steinernematidae | parasite | Poinar et al. (1977) |
| | *Oniscus laevis* (Koch) | Isopoda | Oniscidae | predator | Monteith (1976) |
| | *Oxidus rathkei* (Koch) | Polydesmida | Paradoxosomatidae | predator | Monteith (1976) |
| | *Porcellio laevis* Latreille [=*Oniscus laevis* (Koch)] | Isopoda | Oniscidae | predator | Monteith (1977) |
| | *Pseudomonas aeruginosa* (Schroeter) Migula | | Bacillaceae | pathogen | Poinar et al. (1977) |
| | *Staphylinus badipes* (LeConte) | Coleoptera | Staphylinidae | predator | Monteith (1976; 1977) |
| | *Streptococcus* sp. | | Streptococcaceae | pathogen | Poinar et al. (1977) |
| | *Trachelipus rathkii* (Koch) [=*Oxidus rathkei* (Koch)] | Polydesmida | Paradoxosomatidae | predator | Monteith (1977) |
| | *Utetes canaliculatus* (Gahan) [=*Opius lectus* Gahan] | Hymenoptera | Braconidae | parasitoid | Monteith (1978) |
| | *Utetes lectoides* (Gahan) [=*Opius lectoides* Gahan] | Hymenoptera | Braconidae | parasitoid | Monteith (1978) |
| *Rhopalosiphum maidis* (Fitch) (Hemiptera: Aphididae) | *Adalia bipunctata* (L.) | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Coccinella novemnotata* Herbst | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Coccinella transversoguttata* Faldermann | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Coccinella trifasciata perplexa* Mulsant | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Coleomegilla maculata lengi* Timberlake | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Cycloneda sanguinea* (L.) | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Hippodamia convergens* Guérin-Méneville | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Hippodamia parenthesis* (Say) | Coleoptera | Coccinellidae | predator | Foott (1974) |
| | *Hippodamia tridecempunctata tibialis* (Say) | Coleoptera | Coccinellidae | predator | Foott (1974) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Rhopalosiphum padi* (L.) (Hemiptera: Aphididae) | *Entomophthora planchoniana* Cornu | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| *Rhyacionia buoliana* Denis & Schiffermüller (Lepidoptera: Tortricidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | parasitoid | Pointing & Green (1962) |
| | *Baryscapus turionum* (Hartig) [=*Tetrastichus turionum* (Hartig)] | Hymenoptera | Eulophidae | parasitoid | Coppel & Arthur (1954); Pointing & Green (1962) |
| | *Campoplex difformis* (Gmelin) [=*Campoplex mutabilis* (Holmgren)] | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Campoplex* sp. | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Copidosoma filicorne* (Dalman) [=*Copidosoma geniculatum* (Dalmen)] | Hymenoptera | Encyrtidae | parasitoid | Coppel & Arthur (1954) |
| | *Eurytoma appendigaster* (Swederus) | Hymenoptera | Eurytomidae | parasitoid | Coppel & Arthur (1954) |
| | *Exeristes comstockii* (Cresson) [=*Calliephialtes comstockii* (Cresson)] | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Exeristes ruficollis* (Gravenhorst) [=*Ephialtes ruficollis* (Gravenhorst)] | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Habrocytus* sp. | Hymenoptera | Pteromalidae | parasitoid | Coppel & Arthur (1954) |
| | *Hyssopus thymus* Girault | Hymenoptera | Eulophidae | parasitoid | Coppel & Arthur (1954) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Itoplectis* sp. | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Orgilus obscurator* (Nees) | Hymenoptera | Braconidae | parasitoid | Coppel & Arthur (1954); Pointing & Green (1962) |
| | *Pimpla* sp. | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Pimpla turionellae* (L.) | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954); Pointing & Green (1962) |
| | *Scambus hispae* (Harris) | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Sinophorus turionum* (Ratzeburg) [=*Campoplex rufifemur* (Thomson)] | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954) |
| | *Temelucha interruptor* (Gravenhorst) [=*Cremastus interruptor* (Gravenhorst)] | Hymenoptera | Ichneumonidae | parasitoid | Coppel & Arthur (1954); Pointing & Green (1962 |
| *Saperda candida* Fabricius (Coleoptera: Cerambycidae) | *Melittobia chalybii* Ashmead | Hymenoptera | Eulophidae | parasitoid | Edwards & Pengelly (1966) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Schistocerca* spp. (Orthoptera: Acrididae) | *Coccobacillus acridiorum* d'Herelle | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| *Scolioneura betuleti* (Klug) (Hymenoptera: Tenthredinidae) | *Chrysocharis laricinellae* (Ratzeburg) | Hymenoptera | Eulophidae | parasitoid | Nystrom & Evans (1989) |
| | *Pnigalio minio* (Walker) | Hymenoptera | Eulophidae | parasitoid | Nystrom & Evans (1989) |
| | *Zagrammosoma multilineatum* (Ashmead) | Hymenoptera | Eulophidae | parasitoid | Nystrom & Evans (1989) |
| *Scolytus multistriatus* (Marsham) (Coleoptera: Curculionidae) | *Parasitaphelenchus oldhami* Rühm | Nematoda | Aphelenchoidae | parasite | Welch (1962) |
| *Sitona cylindricollis* Fåhraeus (Coleoptera: Curculionidae) | *Anaphes diana* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sitona hispidulus* (Fabricius) (Coleoptera: Curculionidae) | *Anaphes diana* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sitona humeralis* Stephens (Coleoptera: Curculionidae) | *Anaphes diana* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| | *Anaphes fuscipennis* Haliday | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| *Sitona lineatus* (L.) (Coleoptera: Curculionidae) | *Anaphes diana* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sitona lineellus* (Bonsdorff) [=*Sitona scissifrons* Say] (Coleoptera: Curculionidae) | *Centistes ater* (Nees) [=*Centistes excrucians* Haliday] | Hymenoptera | Braconidae | parasitoid | Loan (1964) |
| | *Perilitus sitonae* (Mason) [=*Microctonus sitonae* Mason] | Hymenoptera | Braconidae | parasitoid | Loan (1964) |
| | *Pygostolus falcatus* (Nees) | Hymenoptera | Braconidae | parasitoid | Loan (1964) |
| *Sitophilus granarius* (L.) (Coleoptera: Curculionidae) | *Bacillus* sp. | | Bacillaceae | pathogen | Morris (1980) |
| *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) | *Bacillus* sp. | | Bacillaceae | pathogen | Morris (1980) |
| | *Pseudomonas* sp. | | Pseudomonadaceae | pathogen | Morris (1980) |
| *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Laing (1989) |
| | *Trichogramma pretiosum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Corrigan et al. (1994) |
| *Solidago canadensis* L. (*Asteraceae*) | *Trihabda borealis* Blake | Coleoptera | Chrysomelidae | phytophage | Reid & Harmsen (1975) |
| | *Trihabda canadensis* (Kirby) | Coleoptera | Chrysomelidae | phytophage | Reid & Harmsen (1975) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| *Sparaganothis distincta* (Walshingham) (Lepidoptera: Tortricidae) | *Enytus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Triclistus* sp. | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| *Sparaganothis reticulatana* (Clemens) (Lepidoptera: Tortricidae) | *Triclistus crassus* Townes & Townes | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| *Sphenophorus australis* Chittenden (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus callosus* (Olivier) (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus costipennis* Horn (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus destructor* Chittenden (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus maidis* Chittenden (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus minimus* Hart. (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus necydaloides* (Fabricius) [=*Sphenophorus necydaloides* Chittenden] (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus parvulus* Gyllenhal (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus venatus* (Say) (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Sphenophorus venatus vestitus* Chittenden (Coleoptera: Curculionidae) | *Anaphes calendrae* (Gahan) | Hymenoptera | Mymaridae | parasitoid | Huber (2006) |
| *Spilonota ocellana* (Denis & Schiffermüller) (Lepidoptera: Tortricidae) | *Bassus dimidiator* (Nees) | Hymenoptera | Braconidae | parasitoid | Hagley & Barber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Colpoclypeus florus* (Walker) | Hymenoptera | Eulophidae | parasitoid | Hagley & Barber (1992) |
| | *Triclistus crassus* Townes & Townes | Hymenoptera | Ichneumonidae | parasitoid | Hagley & Barber (1992) |
| | *Trichogramma minutum* Riley | Hymenoptera | Trichogrammatidae | parasitoid | Hagley & Barber (1992) |
| *Stethorus punctum* (LeConte) (Coleoptera: Coccinellidae) | *Anthocoris musculus* (Say) | Hemiptera | Anthocoridae | predator | Robinson (1952) |
| | *Chrysopa* spp. | Neuroptera | Chrysopidae | predator | Robinson (1952) |
| | *Orius insidiosus* (Say) | Hemiptera | Anthocoridae | predator | Robinson (1952) |
| *Tabanus affinis* Kirby (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| *Tabanus frontalis-septentrionalis* complex (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| *Tabanus* sp. (Diptera: Tabanidae) | *Diglochis occidentalis* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | James (1952) |
| | *Mermis* sp. | Mermithida | Mermithidae | parasite | James (1952) |
| *Tarsonemus confusus* Ewing (Trombidiformes: Tarsonemidae) | *Amblyseius fallacis* Garman | Megostigmata | Phytoseiidae | predator | Villanueva & Harmsen (1996) |
| *Tetranychus mcdanieli* McGregor [=*Eotetranychus mcdanieli* (McGregor)] (Trombidiformes: Tetranychidae) | *Adalia bipunctata* (L.) | Coleoptera | Coccinellidae | predator | Robinson (1952) |
| | *Aeolothrips melaleucus* Haliday | Thysanoptera | Aelothripidae | predator | Robinson (1952) |
| | *Anthocoris musculus* (Say) | Hemiptera | Anthocoridae | predator | Robinson (1952) |
| | *Anystis agilis* Banks | Trombidiformes | Anystidae | predator | Robinson (1952) |
| | *Chrysopa chi* Fitch | Diptera | Chrysopidae | predator | Robinson (1952) |
| | *Chrysoperla carnea* (Stephens) [=*Chrysopa harrisii* var. *externa* Hagen] | Diptera | Chrysopidae | predator | Robinson (1952) |
| | *Chrysoperla carnea* (Stephens) [=*Chrysopa plorabunda* var. *californica* Coquillett] | Diptera | Chrysopidae | predator | Robinson (1952) |
| | *Diaphnidia pellucida* Uhler | Hemiptera | Miridae | predator | Robinson (1952) |
| | *Feltiella* sp. | Diptera | Cecidomyiidae | predator | Robinson (1952) |
| | *Haplothrips faurei* Hood | Thysanoptera | Phlaeothripidae | predator | Robinson (1952) |
| | *Hemerobius simulans* Walker | Neuroptera | Hemerobiidae | predator | Robinson (1952) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Hemerobius stigmaterus* Fitch | Neuroptera | Hemerobiidae | predator | Robinson (1952) |
| | *Hyaliodes virtripennis* (Say) | Hemiptera | Miridae | predator | Robinson (1952) |
| | *Hyaloides harti* Knight | Hemiptera | Miridae | predator | Robinson (1952) |
| | *Nabis ferus* (L.) | Hemiptera | Nabidae | predator | Robinson (1952) |
| | *Orius insidiosus* (Say) | Hemiptera | Anthocoridae | predator | Robinson (1952) |
| | *Plagiognathus obscurus* (Uhler) | Hemiptera | Miridae | predator | Robinson (1952) |
| | *Scolothrips sexmaculatus* (Pergande) | Thysanoptera | Thripidae | predator | Robinson (1952) |
| | *Stethorus punctum punctum* (LeConte) | Coleoptera | Coccinellidae | predator | Robinson (1952; 1953) |
| | *Stilbus probatus* Casey | Coleoptera | Phalacrididae | predator | Robinson (1952) |
| | *Toxomerus geminatus* (Say) | Diptera | Syrphidae | predator | Robinson (1952) |
| | *Typhlodromus fallacis* (Garman) | Mesostigmata | Phytoseiidae | predator | Robinson (1952) |
| | *Typhlodromus longipilus* Nesbit | Mesostigmata | Phytoseiidae | predator | Robinson (1952) |
| *Tetranychus pacificus* McGregor [=*Eotetranychus pacificus* (McGregor)] (Trombidiformes: Tetranychidae) | *Stethorus punctum punctum* (LeConte) | Coleoptera | Coccinellidae | predator | Robinson (1952; 1953) |
| *Tetranychus urticae* Koch (Trombidiformes: Tetranychidae) | *Balaustium putnami* Smiley | Trombidiformes | Erythraeidae | predator | Cadogan & Laing (1982) |
| | *Phytoseiulus persimilis* Athias-Henriot | Mesostigmata | Phytoseiidae | predator | Jones et al. (2006) |
| | *Zetzellia mali* (Ewing) | Trombidiformes | Stigmaeidae | predator | Woolhouse & Harmsen (1985) |
| *Thymelicus lineola* (Ochsenheimer) (Lepidoptera: Hesperiidae) | *Camposcopus* sp. [=*Labrorychus* sp.] | Hymenoptera | Ichneumonidae | parasitoid | Pengelly (1961) |
| | *Casinaria* sp. A [=*Horogenes* sp. A] | Hymenoptera | Ichneumonidae | parasitoid | Pengelly (1961) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Pengelly (1961) |
| | *Meteorus hyphantriae* Riley | Hymenoptera | Braconidae | parasitoid | Pengelly (1961) |
| | *Pimpla pedalis* Cresson | Hymenoptera | Ichneumonidae | parasitoid | Pengelly (1961) |
| | *Rogas* sp. | Hymenoptera | Braconidae | parasitoid | Pengelly (1961) |
| *Tomicus piniperda* (L.) (Coleoptera: Curculionidae) | *Coeloides pissodis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| | *Corticeus praetermissus* (Fall) | Coleoptera | Tenebrionidae | predator | Bright (1996) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Dinotiscus dendroctoni* (Ashmead) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| | *Eupelmus* sp. | Hymenoptera | Eupelmidae | parasitoid | Bright (1996) |
| | *Eurytoma* sp. | Hymenoptera | Eurytomidae | parasitoid | Bright (1996) |
| | *Medetera pinicola* Kowarz | Diptera | Dolichopodidae | predator | Bright (1996) |
| | *Medetera signaticornis* (Loew) | Diptera | Dolichopodidae | predator | Bright (1996) |
| | *Platysoma gracile* LeConte [=*Cylistix gracilis* (LeConte)] | Coleoptera | Histeridae | predator | Bright (1996) |
| | *Rhopalicus tutela* (Walker) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| | *Roptrocerus xylophagorum* (Ratzeburg) | Hymenoptera | Pteromalidae | parasitoid | Bright (1996) |
| | *Spathius* sp. | Hymenoptera | Braconidae | parasitoid | Bright (1996) |
| *Tortrix* sp. (Lepidoptera: Tortricidae) | *Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley] | Hymenoptera | Braconidae | parasitoid | Laing & Heraty (1982) |
| *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae) | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Jaques (1971) |
| | *Bacillus thuringiensis* Berliner *serovar. alestii* | | Bacillaceae | pathogen | Angus & Heimpel (1960) |
| | *Compsilura concinnata* (Meigen) | Diptera | Tachindae | parasitoid | Harcourt (1963) |
| | *Copidosoma floridanum* (Ashmead) | Hymenoptera | Encyrtidae | parasitoid | Murillo et al. (2012) |
| | *Copidosoma truncatellum* (Dalman) | Hymenoptera | Encyrtidae | parasitoid | Harcourt (1963) |
| | *Cotesia marginiventris* (Cresson) | Hymenoptera | Braconidae | parasitoid | Murillo et al. (2012) |
| | *Cotesia plathypenae* (Muesebeck) | Hymenoptera | Braconidae | parasitoid | Murillo et al. (2012) |
| | *Euplectrus* sp. | Hymenoptera | Eulophidae | parasitoid | Murillo et al. (2012) |
| | *Exeristes comstockii* (Cresson) [=*Campoletis sonorensis* (Cameron)] | Hymenoptera | Ichneumonidae | parasitoid | Murillo et al. (2012) |
| | *Itoplectis conquisitor* (Say) | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Meteorus* sp. | Hymenoptera | Braconidae | parasitoid | Murillo et al. (2012) |
| | *Microplitis alaskensis* (Ashmead) | Hymenoptera | Braconidae | parasitoid | Murillo et al. (2012) |
| | *Neoaplectana* n. sp. (DD136) | Rhabditida | Steinernematidae | parasite | Welch & Briand (1961) |
| | *polyhedrosis virus* | | *Baculoviridae* | pathogen | Cameron (1969) |
| | sp. | Hymenoptera | Braconidae | parasitoid | Murillo et al. (2012) |
| | sp. | Hymenoptera | Tachinidae | parasitoid | Murillo et al. (2012) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Stenichneumon culpator cincticornis* (Cresson) | Hymenoptera | Ichneumonidae | parasitoid | Harcourt (1963) |
| | *Trichomalopsis viridiscens* (Walsh) [=*Eupteromalus viridescens* (Walsh)] | Hymenoptera | Pteromalidae | parasitoid | Harcourt (1963) |
| | *Trichoplusia ni NPV* (TnNPV) | | *Baculoviridae* | pathogen | Jaques (1971) |
| host species not specified (Diptera: Culicidae) | *Dolichopus appendiculatus* Van Duzee | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Dolichopus nigricauda* Van Duzee | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Dolichopus rendescens* Melander & Brues | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Dolichopus walkeri* Van Duzee | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Dugesia dorotocephala* (Woodworth) | Tricladida | Duegesiidae | predator | George (1979; 1984) |
| | *Erynia dipterigena* (Thaxter) Remaudière & Keller | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Pelastoneurus* sp. | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| | *Thinophilus* sp. | Diptera | Dolicopodidae | predator | Laing & Welch (1963) |
| host species not specified (Diptera: Lauxaniidae) | *Erynia echinospora* (Thaxter) Remaudière & Keller | | Entomophthoraceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| host species not specified (Hemiptera: Aphididae) | *Conidiobolus obscurus* (Hall & Dunn) Remaudière & Keller | | Ancylistaceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Conidiobolus thromboides* Dreschler | | Ancylistaceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| | *Neozygites fresenii* (Thaxter) Remaudière & Keller | | Neozygiotaceae | pathogen | Ben-Ze'ev & Jaques (1990) |
| host species not identified (Lepidoptera/Diptera) | *Pediobius* sp. [=Pleurotropis sp.] | Hymenoptera | Eulophidae | parasitoid | Judd (1953) |
| host species not specified (Lepidoptera) | *Microgaster hospes* Marshall [=*Microgaster ?comptanae* Viereck | Hymenoptera | Braconidae | parasitoid | Judd (1953) |
| host species not specified (Orthoptera: Acrididae) | *Aerobacter aerogenes* [=*Coccobacillus acridiorum* D'Herelle] | | Enterobacteriaceae | pathogen | Cameron (1969) |
| host species not specified | *Acholla multispinosa* (DeGeer) | Hemiptera | Reduviidae | predator | Hagley (1979) |
| | *Allograpta olbiqua* (Say) | Diptera | Syrphidae | predator | Hagley (1979) |
| | *Anaphes alaskae* Annecke & Doutt | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes amplipennis* Ogloblin | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Anaphes fabarius* (Rondani) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes hercules* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes hundsheimensis* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes inexpectatus* Huber & Prinsloo | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes intermedius* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes medius* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes nitens* (Girault) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes nunezi* Ogloblin | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes pectoralis* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes pucarobius* Ogloblin | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes sinipennis* Girault | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes stubaiensis* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes superadditus* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes tasmaniae* Huber & Prinsloo | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anaphes wolfsthali* (Soyka) | Hymenoptera | Mymaridae | parasitoid | Huber (1992) |
| | *Anatis labiculata* (Say) [=*Anatis quindecimpunctata* (Olivier)] | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Anisoplia austraca* Herbst | | Clavicipitaceae | pathogen | Cameron (1953) |
| | *Anthocoris nemoralis* (Fabricius) | Hemiptera | Anthocoridae | predator | Hagley (1979) |
| | *Aspergillus flavus* Link | | Trichocomaceae | pathogen | Cameron (1952) |
| | *Bacillus anthracis* Cohn | | Bacillaceae | pathogen | Cameron (1969) |
| | *Bacillus cereus* Frankland & Frankland | | Bacillaceae | pathogen | Cameron (1952; 1969) |
| | *Bacillus proteus* (Bach) | | Bacillaceae | pathogen | Cameron (1952) |
| | *Bacillus subtilis* (Ehrenberg) | | Bacillaceae | pathogen | Cameron (1952) |
| | *Bacillus thuringiensis* Berliner | | Bacillaceae | pathogen | Cameron (1952; 1969) |
| | *Beauveria bassiana* (Balsamo) Vuillemin [=*Botrytis bassiana* Balsamo] | | Moniliaceae | pathogen | Cameron (1952) |
| | *Beauveria* spp. | | Clavicipitaceae | pathogen | Cameron (1969) |
| | *Campylomma verbasci* (Meyer-Dür) | Hemiptera | Miridae | predator | Hagley (1979) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Cantharis* sp. | Coleoptera | Cantharidae | predator | Hagley (1979) |
| | *Chilocorus stigma* (Say) [=*Chilocoris bivulneratus* Mulsant] | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Chrysopa oculata* (Say) | Neuroptera | Chrysopidae | predator | Hagley (1979) |
| | *Coccinella novemnotata* Herbst | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Coccinella transversoguttata richarsoni* Brown | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Coccinella undecimpunctata* L. | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Coelomegilla maculata lengi* Timberlake | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Cycloneda munda* (Say) | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Enterobacter aerogenes* Hormaeche & Edwards [=*Aerobacter aerogenes* =*Coccobacillus acridiorum* d'Herelle] | | Enterobacteriaceae | pathogen | Cameron (1952) |
| | *Entomophthora* spp. | | Entomophthoraceae | pathogen | Cameron (1969) |
| | *Eupiodes americanus* Wiedemann [=*Metasyruphus americanus* (Wiedemann)] | Diptera | Syrphidae | predator | Hagley (1979) |
| | *Haplothrips fauerei* Hood | Thysanoptera | Phlaeothripidae | predator | Hagley (1979) |
| | *Haplothrips subtilissimus* (Haliday) | Thysanoptera | Phlaeothripidae | predator | Hagley (1979) |
| | *Hemerobius humulinus* (L.) | Neuroptera | Hemerobiidae | predator | Hagley (1979) |
| | *Hemerobius* sp. | Neuroptera | Hemerobiidae | predator | Hagley (1979) |
| | *Hyalioides vitripennis* (Say) | Hemiptera | Miridae | predator | Hagley (1979) |
| | *Hyperaspis undulata* (Say) | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Isaria larinosa* (Holmskiold) Fries [=*Spicaria larinosa* (Holmskiold)] | | Moniliaceae | pathogen | Cameron (1952) |
| | *Mantis religiosa* L. | Orthoptera | Mantidae | predator | James (1959) |
| | *Metarrhizium anisopliae* (Metchnikoff) Sorokin | | Clavicipitaceae | pathogen | Cameron (1952) |
| | *Myzia* sp. [=*Neomysia* sp.] | Coleoptera | Coccinellidae | predator | Hagley (1979) |
| | *Nabis subcoleoptratus* (Kirby) | Hemiptera | Nabidae | predator | Pengelly (1961) |
| | *Paenibacillus popilliae* Dutkey [=*Bacillus popilliae* Dutkey] | | Paenibacillaceae | pathogen | Cameron (1952; 1969) |

APPENDIX A continued...

| Host | Natural enemy | Order | Family | Feeding niche | Reference |
|---|---|---|---|---|---|
| | *Pilophrous perplexus* Dove & Scott | Hemiptera | Miridae | predator | Hagley (1979) |
| | *Plagiognathus obscurus* Uhler | Hemiptera | Miridae | predator | Hagley (1979) |
| | *Podabrus* sp. | Coleoptera | Cantharidae | predator | Hagley (1979) |
| | *Podisus* sp. | Hemiptera | Pentatomidae | predator | Hagley (1979) |
| | *polyhedral virus* | | *Baculoviridae* | pathogen | Cameron (1952) |
| | *Reduviuus personatus* (L.) | Hemiptera | Reduviidae | predator | Hagley (1979) |
| | *Thrips calcaratus* Uzae | Thysanoptera | Thripidae | predator | Hagley (1979) |
| | *Trichogramma evanescens* Westwood | Hymenoptera | Trichogrammatidae | parasitoid | Griffiths (1972) |

# ONTARIO RECORDS OF *SPERCHOPSIS TESSELLATA* (ZIEGLER), A RARELY COLLECTED LOTIC WATER SCAVENGER BEETLE (COLEOPTERA, HYDROPHILIDAE)

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*Sperchopsis* LeConte is a distinctive monotypic eastern North American genus of water scavenger beetles including only *S. tessellata* (Zeigler), a rarely collected species restricted to the margins of cold, clear, rapidly flowing streams where it prefers undercut sandy or gravelly banks. Spangler (1961) reviewed the distribution and biology of *S. tessellata,* recording it from the Canadian provinces of Nova Scotia and Quebec as well as from localities throughout eastern United States. Smetana (1988), in his important review of the Hydrophilidae of Canada, provides only three Canadian collection records for *S. tessellata*: one from Nova Scotia, one from Quebec and one from New Brunswick. Roughley (1991) used Smetana's review as the basis for a checklist of Hydrophilidae of Canada, but gave the known Canadian distribution of *S. tessellata* as Nova Scotia, Quebec and Ontario instead of Nova Scotia, New Brunswick, and Quebec. There are no Ontario specimens of *S. tessellata* in the Wallis-Roughley Museum of Entomology (University of Manitoba) so Roughley's listing of *Sperchopsis* from Ontario was probably a *lapsus*. The relatively large (about 7 mm long), strikingly convex, pitted adults of this species are easily distinguished from other water scavenger beetles, so it is unlikely that it would be overlooked in collections or samples from aquatic insect surveys. The new Ontario records of *Sperchopsis* given below are based on the only known Ontario collections of the genus.

I first collected and identified this species from Ontario in 1976, from the Credit River near Belfountain in Wellington County. Despite subsequent searching in apparently suitable parts of other streams and rivers in southern Ontario (including the Eramosa, Saugeen, Speed, Grand, Sauble, Rankin and Crane Rivers), no further *Sperchopsis* specimens were found until 2007 and 2008, when one beetle was found on rotting wood embedded in an undercut sandy bank in the Credit River near Erin, and another was collected in the Credit River very close to where the first Ontario specimen had been collected 31 years earlier.

Data for the Ontario specimens of *Sperchopsis*, all deposited in the University of Guelph Insect Collection, are as follows (latitude and longitude are not on the original label): Ontario, Wellington County, Belfountain, Credit River, 43°48′6.56″N 79°59′47.10″W, April 3, 1976, S. A. Marshall; Belfountain at the fork of the Credit River, May 5, 2007, Adam Brunke; Ontario, Wellington County, Credit River at the crossing of highway 124 near Erin, 43°50′6.01″N 80° 1′20.04″W, May 1, 2008, S. A. Marshall.

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FIGURE 1. Adult *Sperchopsis tessellata* from the Credit River, Ontario. Body length approximately 7 mm.

In view of the general rarity, taxonomic distinctness, and restricted habitat of this beetle, it is of potential importance as a species of conservation concern in Ontario.

## Acknowledgements

Thanks to Miles Zhang for confirming that there are no Canadian *Sperchopsis* specimens in the J. B. Wallis museum.

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# *IDIOTYPA CLAVATA* (PROVANCHER, 1888) (HYMENOPTERA: DIAPRIIDAE), NEW GENERIC PLACEMENT FOR A MISCLASSIFIED SPECIES

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In 1888, Provancher (1889) described *Camptoptera* (as "*Camptotera*") *clavata* from a male and a female collected at Ste. Gertrude, Quebec, though he did not note the actual number of specimens examined. Presumably it was only two. He also did not designate a primary type. Girault (1911) borrowed what was thought to be the unique specimen of *C. clavata,* labelled "*Camptotera clavata* Prov. 1598", but it arrived badly damaged so he could only state that it definitely did not belong to Mymaridae. Girault remounted the fragments remaining—initially stated to be "a single fore wing and several tarsi"; later in the same description corrected to "these notes are based on a fore wing and tibiae and tarsi of two legs"—in Canada balsam on a slide and described the fore wing venation and leg remnants before returning the specimen to the sender, Abbé V.A. Huard, Musée de l'Instruction Publique, Quebec [City]. Girault's designation must be construed as a lectotype designation according to ICZN Article 73.1.3 and Recommendation 73F: "Where no holotype or syntype was fixed for a nominal species-group taxon established before 2000, and when it is possible that the nominal species-group taxon was based on more than one specimen, an author should proceed as though syntypes may exist and, where appropriate, should designate a lectotype rather than assume a holotype." Gahan and Rohwer (1917) correctly treated Girault's "type" as a lectotype.

At my request, J. Perron, retired curator of the Provancher Collection, searched for the Girault slide and noted that it had been lost. So nothing at all remains of the lectotype. However, he found another specimen labeled in Provancher's hand as *C. clavata* (Fig. 1) and sent it to me for study. It is unquestionably one of the syntypes because its label number #616 (Fig. 1) corresponds to catalogue number 1598 of Provancher's personal collection, which is the number of the lost type seen by Girault (J.-M. Perron, personal communication). It is a species of *Trichopria* (Diapriidae) (Figs. 1–5), similar to *T. virginica* (Ashmead) (L. Masner, personal communication).

Peck (1963) catalogued the literature on *C. clavata*. Both he and Burks (1979) had treated the species as unplaced within Chalcidoidea, even though Girault (1911) had stated "The fore wing . . . has the venation of a Pteromalid". The question is whether Girault's brief description of those remnants actually fits that of a North American species of Pteromalidae. If the Code is scrupulously followed, only Girault's redescription of the lectotype can be used to determine the correct identity of *Camptoptera clavata*. Provancher's original description must be disregarded, because it did not explicitly include a type designation,

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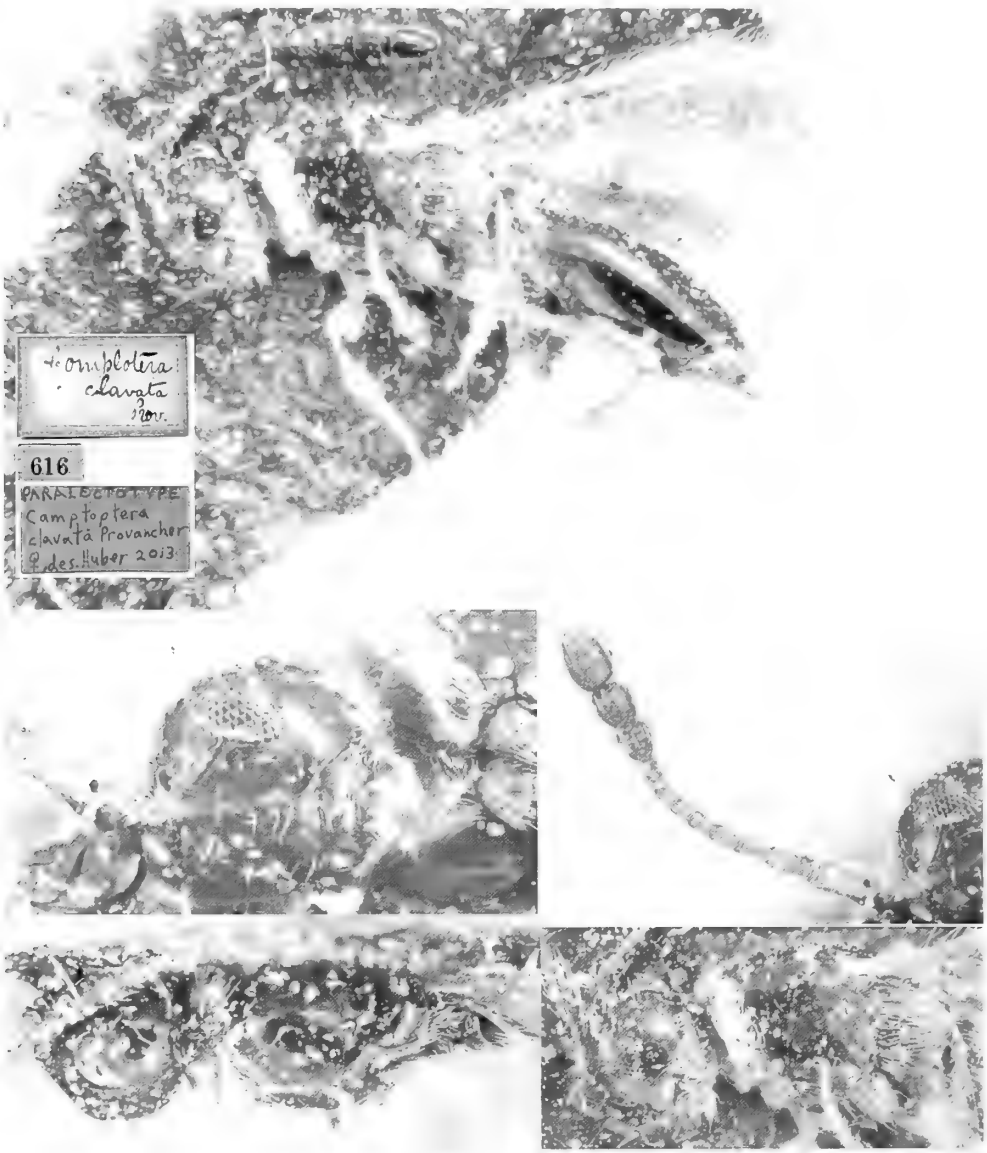


FIGURES 1–5. *Camptoptera clavata*, paralectotype female. 1, habitus, lateral; insert: labels. 2, head, anteroventral. 3, antenna, dorsal. 4, head and thorax, dorsal. Scale for Fig. 1 = 1 mm.

and the second Provancher syntypical specimen of *C. clavata* is not a name-bearing type. Yet, based on Provancher's original description and the only remaining specimen of the syntype series (the paralectotype) *C. clavata* could also be a species of Diapriidae.

Girault described the fore wing venation as "the costal cell is well developed, the submarginal vein long and slender, eight or more times longer than the short, straight, broad marginal vein, which is twice the length of the stigmal vein, which is distinct but

without a neck; postmarginal vein somewhat shorter than the stigmal and short and broad, subconic. Apex of the submarginal vein just before it joins the submarginal is colorless." No Nearctic member of Pteromalidae remotely fits Girault's description of the venation. The only Nearctic pteromalid that has a relatively short, straight and broad marginal vein is *Pachyneuron mucronatum* Girault but in this genus the submarginal vein is much less than eight times the length of the marginal which, in turn, is about as long as the stigmal vein and the postmarginal vein is longer than the stigmal vein. As for the tibia and 5-segmented tarsi, no species of Pteromalidae exactly fits Girault's description: "The tarsi are 5-jointed, with the spur forked and the strigil well-developed on the cephalic legs. The proximal tarsal joint is long. The tibiae are curved and enlarged distad, almost club-shaped. The proximal tarsal joint of the cephalic legs is curved at the base." In contrast, Girault's description fits almost perfectly species of *Idiotypa* (Diapriidae) (Masner, personal communication and my own examination of Nearctic specimens). Thus, both the lectotype and paralectotype are shown to belong to the same family, i.e., Diapriidae, though unfortunately not to the same genus. *Camptoptera clavata* is therefore removed from being an unplaced genus within Chalcidoidea, as catalogued by Peck (1963) and Burks (1979), and is here placed in *Idoiotypa* (Diapariidae) as *I. clavata* (Provancher), **comb. n.**

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I thank J. M. Perron for finding and sending me the only remaining specimen of *Camptoptera clavata*, informing me about the correspondence of catalogue numbers for this species. My retired colleague, L. Masner (Canadian National Collection of Insects, Ottawa), kindly checked the generic placement of the paralectotype and suggested its likely relationships. J. Read is thanked for taking the photographs and preparing the plate.

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# NEW ONTARIO RECORDS FOR *NANOPHYES M. MARMORATUS* (GOEZE, 1777) (COLEOPTERA: BRENTIDAE), INTRODUCED INTO NORTH AMERICA FOR CLASSICAL BIOLOGICAL CONTROL OF PURPLE LOOSESTRIFE

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In 1992, *Nanophyes marmoratus marmoratus* (Goeze) (Coleoptera: Brentidae), the Purple Loosestrife Flower Weevil, native to Eurasia (Thompson et al. 1987), was identified as a candidate for biological control of Purple Loosestrife, *Lythrum salicaria* (L.) (*Lythraceae*), an alien weed invasive in North America. Although *N. m. marmoratus* was assessed as having a lower potential impact than the other biological control candidates, *Neogalerucella calmariensis* L., *N. pusilla* (Duftschmid) (Chrysomelidae) and *Hylobius transversovittatus* (Goeze) (Curculionidae), it was still released due to its high likelihood of establishment (Blossey and Schroeder 1995). From 1994–2005, *N. m. marmoratus* was released in several US states (Skinner 1996; Blossey 2001). In Canada, 720 adults were released in 1997 in southern Manitoba in three marshy sites (Lindgren et al. 2002). In Ontario there is no record of this species ever having been released (D. Mackenzie, personal communication). The present study is the first to monitor the spread of *N. m. marmoratus* in Canada since its release in North America, thus addressing Corrigan et al.'s (2013) recommendation to assess its establishment in Canada.

*Nanophyes m. marmoratus* adults are small (1.4–2.1 mm long), with light yellowish-brown elytral markings and a long rostrum. Females (Fig. 1a) are slightly larger and with more yellow on the elytra than males (Fig. 1b). The life cycle (egg to adult emergence) is about four weeks. The weevils first appear in mid-spring, when they mate on the flowering inflorescences before laying eggs singly in flower buds (Batra et al. 1986; Blossey and Schroeder 1995). The young whitish larvae feed on the stamens and ovary of unopened flower (Wilson et. al. 2004). The adult beetles emerge, feed on foliage and mate in late August before overwintering in leaf litter (Lindgren et al. 2002).

In 2012 and 2013 several Purple Loosestrife populations in eastern Ontario were surveyed. Only the well-established, leaf-feeding *Neogalerucella* beetles were expected to be found but *Nanophyes m. marmoratus* was repeatedly discovered as well, on Purple Loosestrife flowers from mid-June to late August. One of these specimens, from Pakenham, ON, 45.3333°N 76.2833°W, 10 September 2012 (1 female, CNC), was reported by Douglas et al. (2013) along with specimens collected in Quebec in 2011 from the area between the Ottawa and St. Lawrence Rivers (Fig. 2). *Nanophyes m. marmoratus* has now been identified at eighteen sites in eastern Ontario (Fig. 2) and quantified in fourteen of them. The average density was 0.78 (± 0.55) weevils per stem (n=513 stems), with a range of 0–14 weevils per stem.

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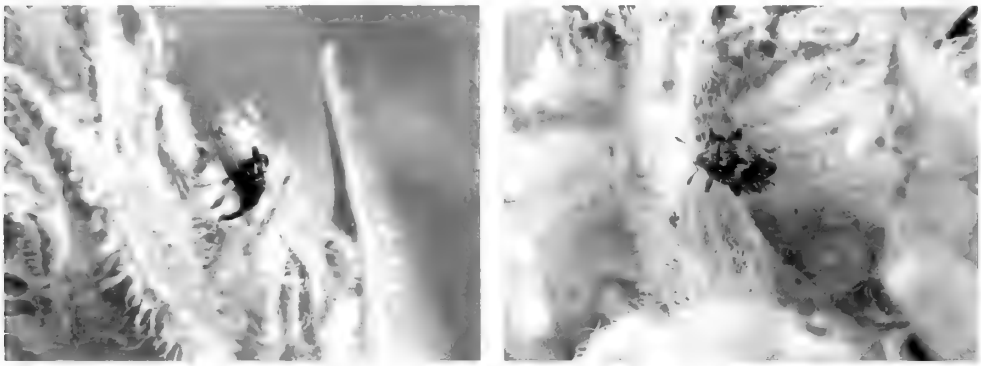

FIGURE 1a. (left) Female and 1b. (right) male *N. m. marmoratus* showing elytral patterns.

Attacked buds do not flower; they become blackened, filled with frass and usually fall off the plant (Wilson et al. 2004). In populations where *N. m. marmoratus* is common, Purple Loosestrife fruit densities are noticeably lower, with higher proportions of aborted seedpods (Fig. 3). Flower bud abortion was often seen on the lower half of the inflorescence with many to all of the buds along this section missing. Affected buds that remain on plants each have a single small exit hole—additional subtle evidence of the weevils' presence. The damaged bud can look very similar to fully developed fruits (seed capsules). Weevil damage is easily spotted and distinguishable from that caused by *Neogalerucella* beetles. The weevils' presence reduces overall seed production. At high weevil densities, larval feeding can reduce fruit output of a Purple Loosestrife plant by up to 70% (Van Dreische


FIGURE 2. Records for *Nanophyes m. marmoratus* in eastern Ontario and southwestern Quebec. Light grey points are new reports, dark grey points are those reported in Douglas (2013).

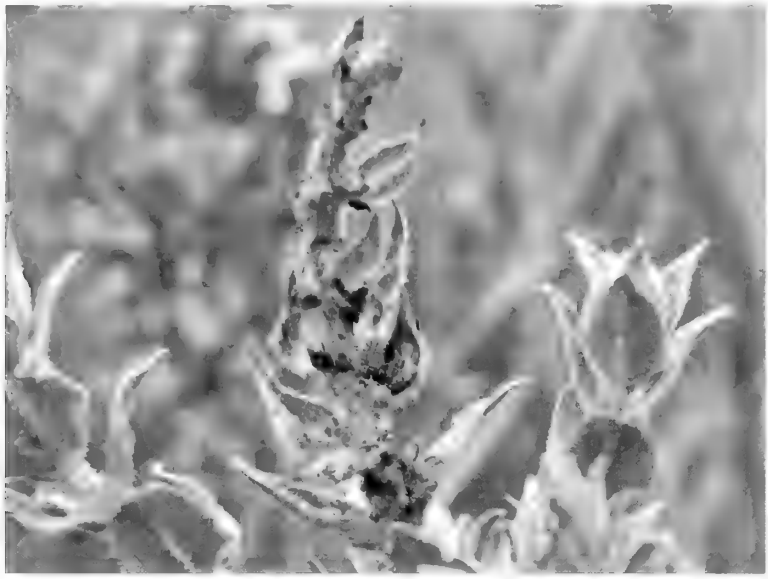

FIGURE 3. Abscission of flower buds caused by *N. m. marmoratus*.

et.al. 2002; personal observation). In the fourteen sites with *N. m. marmoratus,* reductions in reproductive output were measured as the portion (%) of the total lengths of inflorescences bearing aborted flower buds. These reductions averaged 12.6% (± 10.6%) with a range of 0–34.5% over all sites. When considering only the damaged plants (n=85) within the sites, total reproductive output reductions averaged 53% (± 26.2%) with a range of 0–100%.

Early in the biocontrol programme, it was thought likely that combining biological control agents would significantly decrease Purple Loosestrife density (Malecki et al. 1993; Blossey and Schroeder 1995; Wilson et al. 2004; Skinner 2006) but Coombs (2004) suggested that *N. m. marmoratus* would thrive when *Neogalerucella* was low or absent. At one Ontario site, anecdotal evidence suggested that obvious niche partitioning occurred; *N. m. marmoratus* was found primarily on host plants situated in a field, whereas *Neogalerucella* beetles were more concentrated on plants in the adjacent, recently-mowed, roadside ditch. The mowed plants had an increased production of tender, young shoots preferred by *Neoalerucella*, whereas unmowed plants in the field retained their flowers, preferred by *Nanophyes m. marmoratus*.

*Nanophyes m. marmoratus* is now present in southwestern Quebec and Ontario (Douglas et al. 2013). In Ontario, over 403 individuals were counted at 18 sites (50 vouchers, University of Ottawa). Populations of *N. m. marmoratus* are present through extensive areas of eastern Ontario, having been found along the Ottawa River watershed from above Petawawa to the National Capital Region and throughout the Rideau waterway from Kingston to Ottawa. Over the last 19 years tens of thousands of these weevils have been released and redistributed in several northeastern states (Blossey, personal communication). The origins of the Ontario populations are likely the closest US release sites, i.e., Buffalo (42.8553°N

78.8552°W) and Laurel Marsh, NY (42.8709°N 77.2424°W), about 300 km from the most southerly Ontario site at Queen's Biological Field Station (44.5681°N 76.3201°W). Though *N. m. marmoratus* dispersal has not been described, Ferrarese and Garono (2010) noted that dispersals across large expanses of open water have occurred in Oregon. They suggested that adults are capable of dispersing 100–300 km/year. Blossey (personal communication), also indicated that *N. m. marmoratus* adults are strong dispersers and have generally spread in a northeastern pattern, helped by the prevailing winds. It would be useful to survey additional areas for the presence of *N. m. marmoratus*, especially those between the original release sites in the USA and Manitoba and the sites mapped here.

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# FIRST RECORDS OF *ZAPRIONUS INDIANUS* GUPTA (DIPTERA: DROSOPHILIDAE) FROM COMMERCIAL FRUIT FIELDS IN ONTARIO AND QUEBEC, CANADA

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*Zaprionus indianus* Gupta (Diptera: Drosophilidae) was described in India (Gupta 1970) (Fig. 1) but is suspected to be native to the Afrotropical Region (Chassagnard and Kraaijveld 1996). In the New World, it was first found in late 1998 in São Paulo, Brazil and has since spread rapidly throughout South and Central America (Vilela 1999; Goni et al. 2001; Tidon et al. 2003). *Zaprionus indianus* was first detected in North America in July 2005 in Florida (Steck 2005) and is now reported from many eastern, central and southwestern states (van der Linde et al. 2006; van der Linde 2013). This species is now globally widespread and considered cosmopolitan, present in temperate and tropical regions (Tidon et al. 2003; Commar et al. 2012).

*Zaprionus indianus* is a generalist, with the ripe fruits of at least 74 plant species in 31 families in Africa recorded as breeding sites (Lachaise and Tsacas 1983). It has a similarly wide host range in South and North America and has become a significant pest of figs (*Ficus carica* L.) in Brazil (Santos et al. 2003; Stein et al. 2003; van der Linde et al. 2006). While *Z. indianus* is often associated with damaged or fallen rotting fruit, larvae are able to invade the soft tissue of figs before harvest and have been reared in Florida from tree-ripened *Malphigia emarginata* (Barbados cherry), *Punica granatum* (pomegranate), *Eriobotrya japonica* (loquat) and *Dimocarpus longan* (longan) (van der Linde et al. 2006; Pasini et al. 2011). In northeastern USA, *Z. indianus* has been reported in high numbers in net collected samples in a vineyard and was found in apple cider vinegar traps in cherry, raspberry and blackberry fields (Biddinger et al. 2012).

Here we report the first records of *Z. indianus* in Canada, with all specimens found in southern Ontario and Quebec. Specimens of *Z. indianus* were found during surveys for *Drosophila suzukii* (Matsumura) in apple cider vinegar traps in pre- and post-harvest fields of

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FIGURE 1. *Zaprionus indianus* from Africa dorsolateral habitus (Photograph by Stephen A. Marshall).

peach, blueberry, raspberry, strawberry, cherry and plums. Many of the Ontario specimens were collected by the Ontario Ministry of Agriculture and Food and Ministry of Rural Affairs (OMAF/MRA); all were identified by M. Miller and S. A. Marshall and deposited in the University of Guelph Insect Collection, Guelph ON (DEBU). The specimens collected in Quebec were identified at the Laboratoire de diagnostique en phytoprotection of Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), confirmed by M. Miller and S. A. Marshall, and deposited in the Collection d'insectes du Québec, Québec QC (CIQ). Voucher specimens from both provinces are deposited in the Canadian National Collection, Ottawa, ON.

**Material examined. ONTARIO**. **Essex.** Near Harrow, blueberries, 10.ix.2013, OMAF/MRA (1♀ 1♂, DEBU). Near Harrow, blueberries, 3.ix.2013, OMAF/MRA (1♀, DEBU). Near Harrow, peaches, 10.ix.2013, OMAF/MRA (21♀ 26♂, DEBU). Near Ruthven, peaches, 12.ix.2013, OMAF/MRA (1♀ 3♂, DEBU). **Chatham-Kent**. Near Blenheim, raspberries, 10.ix.2013, J. Renkema (1♀, DEBU). Near Blenheim, raspberries, 10.ix.2013, OMAF/MRA, (1♀ 1♂, DEBU). Near Blenheim, 2.ix.2013, J. Renkema (1♀, DEBU). **Niagara.** Near Beamsville, plums, 12.ix.2013, OMAF/MRA, (1♀ 1♂, DEBU). Near Niagara-on-the-Lake, cherries, 11.ix.2013, OMAF/MRA, (1♂, DEBU). **Simcoe.** Near Barrie, peaches, 10.viii.2013, H. Fraser (1♀, DEBU). **QUEBEC**. **Château-Richer**. La Côte-de-Beaupré, strawberries, 2.x.2013, MAPAQ (1♀, CIQ). **Compton**. Coaticook, raspberries, 7.x.2013, MAPAQ (1♂, CIQ). **Laval**. Laval, strawberries, 7.x.2013, MAPAQ (1♀, CIQ). Laval, strawberries, 15.x.2013, MAPAQ (1♀, CIQ). **Pierreville**. Nicolet-Yamaska, strawberries, 8.vii.2013, MAPAQ (1♀, CIQ). Nicolet-Yamaska, raspberries, 19.viii.2013, MAPAQ (1♀, CIQ). **Sainte-Pétronille**. L'Île-d'Orléans, raspberries, 3.x.2013, MAPAQ (1♀,

FIGURE 2. *Zaprionus indianus* from Ontario, Canada, male, lateral habitus.

CIQ). **Sainte-Sabine**. Brome-Missisquoi, strawberries, 6.ix.2013, MAPAQ (1♀, CIQ). Brome-Missisquoi, strawberries, 10.x.2013, MAPAQ (CIQ). **Salaberry-de-Valleyfield**. Beauharnois-Salaberry, raspberries, 17.ix.2013, MAPAQ (1♂, CIQ). **Yamaska**. Pierre-De Saurel, blueberries, 21.viii.2013, MAPAQ (1♂, CIQ).

*Zaprionus indianus* is the only member of *Zaprionus* Coquillett present in Canada to date. It is distinguished from all other Canadian Drosophilidae by its reddish-brown head and thorax with unique silvery stripes that extend dorsally from the antennae to the tip of the scutellum (Fig. 3) and laterally from the leading edge of the thorax to the base of each wing (Fig. 2) (Gupta 1970; Steck 2005; van der Linde et al. 2006; Yassin and David 2010). Because future invasion by other *Zaprionus* species is possible (van der Linde 2010), including the invasive *Z. tuberculatus* Malloch, currently established in Egypt and Israel, and the potentially invasive *Z. ghesquieri* Collart, introduced to Hawaii and Cyprus, but without established populations (Patlar et al. 2012; Yassin A, 2013, pers. comm.) we provide additional features that would confirm that specimens are *Z. indianus*.

The keys to African (Yassin and David 2010) and European (Bächli et al. 2004) *Zaprionus* species, the description in van der Linde (2010), and the original species description by Gupta (1970) were used to identify our specimens of *Z. indianus*. *Zaprionus indianus* specimens have 4–6 composite spines with second short branches arising directly from the fore femur (a character of all 15 members of the *vittiger* species group) (Fig. 4); the silver stripes with black borders are narrow and the black borders do not widen at the scutellum; the scutellum lacks a white tip; the abdomen is light yellow; and the subapical setae on the fourth and fifth abdominal tergite arise from dark spots. In males, the aedeagal flap is smooth apically and serrated basally (distinguishing it from *Z. africanus* Yassin and David with a deeply serrated apical margin and *Z. gabonicus* Yassin and David with a

FIGURE 3. *Zaprionus indianus*, head and thorax, dorsal view.

FIGURE 4. *Zaprionus indianus*, fore femur, lateral view, showing the composite spines.

complete lack of serration apically and basally). In females, the oviscape has six peg-like ovisensilla (*Z. africanus* with 7 or 8 ovisensilla), and the spermatheca length to width ratio is 0.95–1.16 (Gupta 1970; Steck 2005; van der Linde et al. 2006; Yassin and David 2010).

*Zaprionus indianus* is unlikely to become an established pest of fruit in Ontario and Quebec. The small numbers of flies we report from Ontario and Quebec suggest *Z. indianus* may have moved in from the United States in late summer and autumn 2013. However, it can adapt to a wide range of climates (Karan et al. 2000), and if it can successfully overwinter it may also spread rapidly in Canada, as evidenced by its rapid expansion in the USA since its first discovery there (van der Linde 2013). Large populations are often observed the year after its initial detection, particularly in urban environments (Ferreira and Tidon 2005). Unlike *D. suzukii*, *Z. indianus* is not known to infest ripe, undamaged fruit, but if it can use ripening fruit already attacked by *D. suzukii*, there is the potential for increased damage to harvested fruit. Therefore, future monitoring for *D. suzukii* should include *Z. indianus*. Further study on the biology and ecology of this fly is warranted, if population levels in Canada are found to increase.

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# FIRST RECORD OF *LILIOCERIS LILII* (COLEOPTERA: CHRYSOMELIDAE) EGGS IN A WILD POPULATION OF *STREPTOPUS AMPLEXIFOLIUS* (*LILIACEAE*)

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*Lilioceris lilii* (Scopoli) (Coleoptera: Chrysomelidae), the Lily Leaf Beetle, is an invasive European species first found at Montreal, Canada, in the 1940s (Gold et al. 2001). It is a serious pest of cultivated *Lilium* spp. and *Fritillaria* spp. (*Liliaceae*) and has spread across southern Canada and northeastern United States (LeSage 1983; Gold et al. 2001). The beetle also poses a threat to native lilies in Ontario and Quebec, including Canada Lily, *Lilium canadense* L., and Wood Lily, *Lilium philadelphicum* L. (Ernst et al. 2007; Bouchard et al. 2008). In fact, in Ontario and Quebec eight out of 20 wild populations of *L. canadense* were infested with *L. lilii* (Bouchard et al. 2008). There are also records of *L. lilii* adults feeding on plants in other liliaceous genera, e.g., *Polygonatum* (Temperé 1926; Fox Wilson 1942), *Streptopus* (Ernst 2007), as well as genera in other families, e.g., *Solanum* (*Solanaceae*) (Temperé 1926).

Kealey (2013) investigated Claspleaf Twistedstalk, *Streptopus amplexifolius* (L.) DC. (*Liliaceae*), as a potential novel host of *L. lilii*. *Streptopus amplexifolius* occurs in rich moist coniferous and deciduous woods in all provinces and territories in Canada and all adjacent states of the USA (Anonymous 2013). This native plant flowers from late spring until mid-summer. *Streptopus amplexifolius* leaves were offered to *L. lilii* larvae to determine survivorship and development time. Leaves of *S. amplexifolius* were collected from a wild population growing in Gatineau Park, Quebec, Canada (45.491°N 75.863°W). Infestations of *L. lilii* were recently reported in urban areas south of Gatineau Park, but no known *L. lilii* populations are established within the Park nor on any wild populations of *S. amplexifolius* (Cappuccino 2013).

During a routine collection of *S. amplexifolius* plants for laboratory tests on June 25, 2013, a row of three *L. lilii* eggs (Fig. 1) was discovered on the underside of a wild *S. amplexifolius* leaf. Surrounding plants were searched for more eggs, though none were discovered, nor was any obvious feeding damage by adults or larvae observed. The *S. amplexifolius* leaf with the *L. lilii* egg mass was carefully removed from the stem and transported to the laboratory. The eggs were left undisturbed, and the leaf was placed on

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moist filter paper in a 60 x 15 mm Petri dish maintained at 23°C, 70% relative humidity and 16:8 L:D, and monitored for larval hatch. The three eggs hatched on June 30th or July 1st. Two first instar larvae were still alive on July 2nd and feeding damage was observed on the leaf whereas the third larva was dead and had not fed. Subsequently both surviving larvae died. The cause of death is unclear.

The eggs (Fig. 1), and hatched larvae (Fig. 2), found in Gatineau Park shared all of the characteristics of *L. lilii*. *Lilioceris lilii* egg masses are distinct: they are laid parallel to leaf veins, in a linear arrangement of 2–16 eggs on the underside of host leaves (Salisbury 2008); eggs are bright red or orange in color, though darken when near hatching, and are covered in a sticky orange layer; individual eggs are 1.0 x 0.5 mm, and masses are laid from March–September (Haye and Kenis 2004); and *Lilioceris lilli* larvae are dirty-orange in color, with a dark head and legs. First instar larvae (Fig. 2) have head capsule widths between 0.36–0.55 mm, and a distinct egg bursting spine is located on the first abdominal segment (Livingston 1996; Cox 1994). Larvae also carry a viscous fecal shield of their own excrement on their backs.

Eggs of other genera within the Criocerinae subfamily may be confused with *L. lilii* eggs. Hosts of *Lema* spp. belong to the distantly related plant families *Solanaceae* and *Asteraceae*, and *Oulema* spp. are on species of *Asteraceae*, *Commelinaceae* and *Poaceae*. The only species of *Neolema* that occurs in Canada, *N. cordata* White, occurs on *Commelinaceae* spp. Two species of *Crioceris* closely resemble *L. lilii* in the larval stage; however, both are closely associated with Asparagales and have distinctly different egg placement and color (White 1993).

This observation marks the first record of *L. lilii* ovipositing on *S. amplexifolius* in nature and this is the first plant species outside the genera *Lilium*, *Fritillaria*, and *Cardocrinium* (the known host genera for this beetle) where both oviposition in nature and successful larval development in the lab have been observed (see Salisbury 2008). Although Ernst et al. (2007) found that larval performance was poor on *S. amplexifolius* leaves in laboratory tests, Kealey (2013) confirmed that almost half (42%) of *L. lilii* larvae can successfully develop to adults on *S. amplexifolius*. This record is also only the second oviposition record for *L. lilii* in North America on a host plant in nature outside of urban areas where development might also be occasionally possible. The observation reported here is likely the result of an adult that emigrated from an urban area. However, it is unknown what the potential is for colonization by *L. lilii* of novel host plants, such as *S. amplexifolius*, in non-urban areas. Among the factors that might encourage a more permanent move to *S. amplexifolius* by *L. lilii* is the enemy-free-space hypothesis in which the herbivore escapes its specialized parasitoid by feeding on a novel host plant (Brown et al. 1995; Rossbach et al. 2006). Further study would help to establish if such events are rare or the first step in adaptation by an invasive alien species to a novel host.

FIGURE 1. *Lilioceris lilii* eggs on *Streptopus amplexifolius* leaf from Gatineau Park, Quebec.

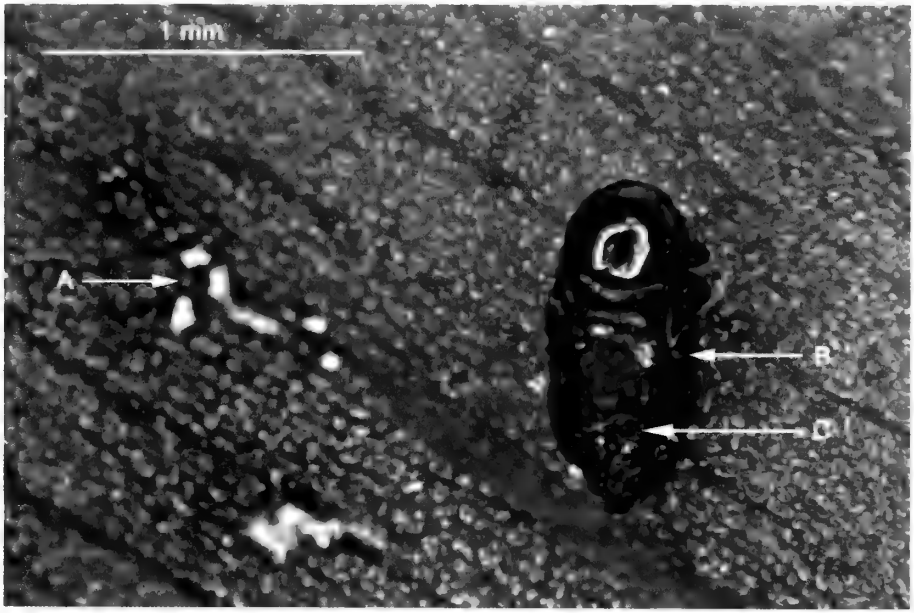


FIGURE 2. *Lilioceris lilii* first instar larva on a *Streptopus amplexifolius* leaf collected from Gatineau Park, Quebec. This picture was taken soon after larval death and shows A) feeding damage B) egg bursters and C) fecal shield characteristic of the species.

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